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

LiDAR Surveys and Flood Mapping of Digos River

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

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College of Engineering
University of the Philippines – Diliman
Quezon City
1101 PHILIPPINES

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For questions/queries regarding this report, contact:

Dr. Joseph E. Acosta
Project Leader, Phil-LiDAR 1 Program
University of the Philippines Mindanao
Davao City, Davao Del Sur, Philippines 8000
jeacosta@up.edu.ph

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

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TABLE OF CONTENTS

LIST OF TABLES ..... **v**
LIST OF FIGURES ..... **vii**
LIST OF ACRONYMS AND ABBREVIATIONS ..... **x**
CHAPTER 1: OVERVIEW OF THE PROGRAM AND DIGOS RIVER **1**
1.1 Background of the Phil-LiDAR 1 Program 1
1.2 Overview of the Digos River Basin 1
CHAPTER 2: LIDAR ACQUISITION OF THE DIGOS FLOODPLAIN **4**
2.1 Flight Plans 4
2.2 Ground Base Stations 6
2.3 Flight Missions 8
2.4 Survey Coverage 9
CHAPTER 3. LIDAR DATA PROCESSING OF THE DIGOS FLOODPLAIN **11**
3.1 Overview of the LiDAR Data Pre-Processing 11
3.2 Transmittal of Acquired LiDAR Data 12
3.3 Trajectory Computation 12
3.4 LiDAR Point Cloud Computation 14
3.5 LiDAR Quality Checking 14
3.6 LiDAR Point Cloud Classification and Rasterization 19
3.7 LiDAR Image Processing and Orthophotograph Rectification 20
3.8 DEM Editing and Hydro-Correction 20
3.9 Mosaicking of Blocks 21
3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model 22
3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model 25
3.12 Feature Extraction 26
3.12.1 Quality Checking of Digitized Features' Boundary 27
3.12.2 Height Extraction 27
3.12.3 Feature Attribution 27
3.12.4 Final Quality Checking of Extracted Features 29
CHAPTER 4. LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE DIGOS RIVER BASIN **30**
4.1 Summary of Activities 30
4.2 Control Survey 31
4.3 Baseline Processing 36
4.4 Network Adjustment 37
4.5 Cross-section, Bridge As-Built, and Water Level Marking 41
4.6 Validation Points Acquisition Survey 45
4.7 River Bathymetric Survey 46
CHAPTER 5. FLOOD MODELING AND MAPPING **49**
5.1 Data Used for Hydrologic Modeling 49
5.1.1 Hydrometry and Rating Curves 49
5.1.2 Precipitation 49
5.1.3 Rating Curves and River Outflow 50
5.2 RIDF Station 51
5.3 HMS Model 52
5.4 Cross-Section Data 57
5.5 Flo 2D Model 57
5.6 Results of HMS Calibration 59
5.7 Calculated Outflow Hydrographs and Discharge Values for Different Rainfall Return Models 61
5.7.1 Hydrograph Using the Rainfall Runoff Model 61
5.7.2 Discharge data using Dr. Horritt's hydrologic method 62
5.8 River Analysis Model Simulation 70
5.9 Flow Depth and Flood Hazard 71
5.10 Inventory of Areas Exposed to Flooding 79
5.11 Flood Validation 142
REFERENCES **145**
ANNEXES **146**
Annex 1. Optech Technical Specification of the Gemini Sensor 146
Annex 2. NAMRIA Certificates of Reference Points Used 147
Annex 3. Baseline Processing Reports of Reference Points Used 148
Annex 4. The Survey Team 149

Annex 5. Data Transfer Sheet for Digos Floodplain.....150
Annex 6. Flight Logs.....151
Annex 7. Flight Status Report.....154
Annex 8. Mission Summary Reports.....158
Annex 9. Digos Model Basin Parameters.....168
Annex 10. Digos Model Reach Parameters.....170
Annex 11. Digos Field Validation.....172
Annex 12. Educational Institutions affected in Digos Floodplain.....177
Annex 13. Health Institutions affected in Digos Floodplain.....180

LIST OF TABLES

Table 1. Digos River Class B Water Quality Assessment 3
Table 2. Digos River Class C Water Quality Assessment 3
Table 3. Flight planning parameters for Gemini LiDAR system 4
Table 4. Details of the recovered NAMRIA horizontal control point DVS-85 used as base station for the LiDAR acquisition 7
Table 5. Details of the recovered horizontal control point BLLM-20 used as base station for the LiDAR acquisition with established coordinates 8
Table 6. Ground control points used during LiDAR data acquisition 8
Table 7. Flight missions for LiDAR data acquisition in Digos floodplain 8
Table 8. Actual parameters used during LiDAR data acquisition 9
Table 9. List of municipalities and cities surveyed during Digos floodplain LiDAR survey 9
Table 10. Self-Calibration Results values for Digos flights 14
Table 11. List of LiDAR blocks for Digos floodplain 15
Table 12. Digos classification results in TerraScan 19
Table 13. LiDAR blocks with its corresponding area 20
Table 14. Shift Values of each LiDAR Block of Digos Floodplain 21
Table 15. Calibration Statistical Measures 24
Table 16. Validation Statistical Measures 25
Table 17. Quality Checking Ratings for Digos Building Features 27
Table 18. Building Features Extracted for Digos Floodplain 28
Table 19. Total Length of Extracted Roads for Digos Floodplain 29
Table 20. Number of Extracted Water Bodies for Digos Floodplain 29
Table 21. List of Reference and Control Points used in Digos River Survey 33
Table 22. Baseline Processing Report for Digos River Basin Static Survey 37
Table 23. Control Point Constraints 38
Table 24. Adjusted Grid Coordinates 38
Table 25. Adjusted geodetic coordinates 39
Table 26. Reference and control points and its location (Source: NAMRIA, UP-TCAGP) 40
Table 27. RIDF values for Davao Rain Gauge computed by PAGASA 51
Table 28. Range of Calibrated Values for Digos River Basin.....60
Table 29. Summary of the Efficiency Test of Digos HMS Model 61
Table 30. Peak values of the Digos HECHMS Model outflow using the Davao RIDF 62
Table 31. Summary of Digos Padada-Mainit river (1) discharge generated in HEC-HMS 68
Table 32. Summary of Digos Padada-Mainit river (2) discharge generated in HEC-HMS 68
Table 33. Summary of Digos Padada-Mainit river (3) discharge generated in HEC-HMS 68
Table 34. Summary of Digos Padada-Mainit river (4) discharge generated in HEC-HMS 68
Table 35. Summary of Digos Padada-Mainit river (5) discharge generated in HEC-HMS 68
Table 36. Summary of Digos Padada-Mainit river (6) discharge generated in HEC-HMS 68
Table 37. Summary of Digos Padada-Mainit river (7) discharge generated in HEC-HMS 69
Table 38. Summary of Digos Padada-Mainit river (8) discharge generated in HEC-HMS 69
Table 39. Summary of Digos Padada-Mainit river (9) discharge generated in HEC-HMS 69
Table 40. Summary of Digos Padada-Mainit river (10) discharge generated in HEC-HMS 69
Table 41. Validation of river discharge estimates 70
Table 42. Municipalities affected in Digos Floodplain 72
Table 43. Affected Areas in Bansalan, Davao del Sur during 5-Year Rainfall Return Period 79
Table 44. Affected Areas in Digos City, Davao del Sur during 5-Year Rainfall Return Period 82
Table 45. Affected Areas in Hagonoy, Davao del Sur during 5-Year Rainfall Return Period 83

Table 46. Affected Areas in Kiblawan, Davao del Sur during 5-Year Rainfall Return Period 86
Table 47. Affected Areas in Kiblawan, Davao del Sur during 5-Year Rainfall Return Period 87
Table 48. Affected Areas in Magsaysay, Davao del Sur during 5-Year Rainfall Return Period 88
Table 49. Affected Areas in Matanao, Davao del Sur during 5-Year Rainfall Return Period 89
Table 50. Affected Areas in Matanao, Davao del Sur during 5-Year Rainfall Return Period 91
Table 51. Affected Areas in Padada, Davao del Sur during 5-Year Rainfall Return Period 93
Table 52. Affected Areas in Santa Cruz, Davao del Sur during 5-Year Rainfall Return Period 94
Table 53. Affected Areas in Sulop, Davao del Sur during 5-Year Rainfall Return Period 95
Table 54. Affected Areas in Sulop, Davao del Sur during 5-Year Rainfall Return Period 96
Table 55. Affected Areas in Sulop, Davao del Sur during 5-Year Rainfall Return Period 96
Table 56. Affected Areas in Columbio, Sultan Kudarat during 5-Year Rainfall Return Period 98
Table 57. Affected Areas in Bansalan, Davao del Sur during 25-Year Rainfall Return Period 98
Table 58. Affected Areas in Digos City, Davao del Sur during 25-Year Rainfall Return Period 99
Table 59. Affected Areas in Hagonoy, Davao del Sur during 25-Year Rainfall Return Period 101
Table 60. Affected Areas in Kiblawan, Davao del Sur during 25-Year Rainfall Return Period 103
Table 61. Affected Areas in Kiblawan, Davao del Sur during 25-Year Rainfall Return Period 105
Table 62. Affected Areas in Magsaysay, Davao del Sur during 25-Year Rainfall Return Period 107
Table 63. Affected Areas in Malalag, Davao del Sur during 25-Year Rainfall Return Period 108
Table 64. Affected Areas in Matanao, Davao del Sur during 25-Year Rainfall Return Period 109
Table 65. Affected Areas in Matanao, Davao del Sur during 25-Year Rainfall Return Period 111
Table 66. Affected Areas in Padada, Davao del Sur during 25-Year Rainfall Return Period 112
Table 67. Affected Areas in Padada, Davao del Sur during 25-Year Rainfall Return Period 113
Table 68. Affected Areas in Santa Cruz, Davao del Sur during 25-Year Rainfall Return Period 114
Table 69. Affected Areas in Sulop, Davao del Sur during 25-Year Rainfall Return Period 115
Table 70. Affected Areas in Sulop, Davao del Sur during 25-Year Rainfall Return Period 116
Table 71. Affected Areas in Sulop, Davao del Sur during 25-Year Rainfall Return Period 117
Table 72. Affected Areas in Columbio, Sultan Kudarat during 25-Year Rainfall Return Period 118
Table 73. Affected Areas in Bansalan, Davao del Sur during 100-Year Rainfall Return Period 119
Table 74. Affected Areas in Digos City, Davao del Sur during 100-Year Rainfall Return Period 120
Table 75. Affected Areas in Hagonoy, Davao del Sur during 100-Year Rainfall Return Period 122
Table 76. Affected Areas in Kiblawan, Davao del Sur during 100-Year Rainfall Return Period 124
Table 77. Affected Areas in Kiblawan, Davao del Sur during 100-Year Rainfall Return Period 127
Table 78. Affected Areas in Magsaysay, Davao del Sur during 100-Year Rainfall Return Period 129
Table 79. Affected Areas in Malalag, Davao del Sur during 100-Year Rainfall Return Period 129
Table 80. Affected Areas in Matanao, Davao del Sur during 100-Year Rainfall Return Period 130
Table 81. Affected Areas in Matanao, Davao del Sur during 100-Year Rainfall Return Period 132
Table 82. Affected Areas in Padada, Davao del Sur during 100-Year Rainfall Return Period 134
Table 83. Affected Areas in Padada, Davao del Sur during 100-Year Rainfall Return Period 135
Table 84. Affected Areas in Santa Cruz, Davao del Sur during 100-Year Rainfall Return Period 136
Table 85. Affected Areas in Sulop, Davao del Sur during 100-Year Rainfall Return Period 137
Table 86. Affected Areas in Sulop, Davao del Sur during 100-Year Rainfall Return Period 138
Table 87. Affected Areas in Sulop, Davao del Sur during 100-Year Rainfall Return Period 138
Table 88. Affected Areas in Columbio, Sultan Kudarat during 100-Year Rainfall Return Period 139
Table 89. Actual Flood Depth vs Simulated Flood Depth in Digos River Basin.....140

LIST OF FIGURES

Figure 1. Map of the Digos River Basin (in brown) 1
Figure 2. Flight plans and base stations used for Digos Floodplain. 5
Figure 3. GPS set-up over DVS-85 located inside Mariano Sarona Elementary School, inside the fence of the flagpole (a) and NAMRIA reference point DVS-85 (b) as recovered by the field team. 6
Figure 4. GPS set-up over BLLM-20 located inside Mariano Sarona Elementary School, inside the fence of the flagpole (a) and NAMRIA reference point BLLM-20 (b) as recovered by the field team 7
Figure 5. Actual LiDAR survey coverage for Digos Floodplain 10
Figure 6. Schematic Diagram for Data Pre-Processing Component 11
Figure 7. Smoothed Performance Metrics of Digos flight 7406GC 12
Figure 8. Solution Status Parameters of Digos Flight 7406GC 13
Figure 9. Best estimated trajectory for Digos Floodplain 14
Figure 10. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Digos Floodplain 15
Figure 11. Image of data overlap for Digos Floodplain 16
Figure 12. Pulse density map of merged LiDAR data for Digos Floodplain 17
Figure 13. Elevation difference map between flight lines for Digos Floodplain. 18
Figure 14. Quality checking for a Digos flight 7406GC using the Profile Tool of QT Modeler 18
Figure 15. Tiles for Digos floodplain (a) and classification results (b) in TerraScan 19
Figure 16. Point cloud before (a) and after (b) classification 19
Figure 17. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Digos Floodplain 20
Figure 18. Portions in the DTM of Digos Floodplain – a building before (a) and after (b) manual editing 21
Figure 19. Map of Processed LiDAR Data for Digos Floodplain 22
Figure 20. Map of Digos Floodplain with validation survey points in green 23
Figure 21. Correlation plot between calibration survey points and LiDAR data 24
Figure 22. Correlation plot between validation survey points and LiDAR data 25
Figure 23. Map of Digos Flood Plain with bathymetric survey points shown in blue 26
Figure 24. QC blocks for Digos building features 27
Figure 25. Extracted features for Digos floodplain 29
Figure 26. Digos River survey extent 31
Figure 27. Overall GNSS Survey loop of Digos River Basin 32
Figure 28. GNSS base receiver setup, Trimble® SPS 852 at DVS-1 at the east side of Pier, in Brgy. Leon Garcia Sr., Davao City, Davao Del Sur. 33
Figure 29. GNSS base receiver setup, Trimble® SPS 882 at DV-76 at the Gov. Miranda Bridge Approach, Brgy. Guadalupe, Municipality of Carmen, Davao Del Norte 34
Figure 30. GNSS base receiver setup, Trimble® SPS 882 at DS-09 located at stair of Nograles Park along Mac Arthur Highway, in Brgy. Talomo, Davao City, Davao Del Sur 34
Figure 31. GNSS base receiver setup, Trimble® SPS 852 at UP-CEB on the right approach of Cebulan Bridge in Brgy Darong, Municipality of Santa Cruz, Davao Del Sur 35
Figure 32. GNSS base receiver setup, Trimble® SPS 882 at UP-DIG, right approach of Digos Bridge in Brgy. Aplaya, Digos City, Davao Del Sur 35
Figure 33. GNSS base receiver setup, Trimble® SPS 852 at UP-LIP2, on the right approach

of Lipadas Bridge along National Highway in Brgy. Lizada, Toril District, Davao Del Sur 36
Figure 34. GNSS base receiver setup, Trimble® SPS 882 at UP-PAD, Padada Bridge, Brgy. Guihing, Municipality of Hagonoy, Davao del Sur 36
Figure 35. Cross-section survey at the downstream side of Digos Bridge in Brgy. Aplaya, Digos City, Davao Del Sur 41
Figure 36. Digos bridge cross-section location map 42
Figure 37. Digos Bridge cross-section diagram 43
Figure 38. Digos Bridge Data Form 44
Figure 39. MSL water level markings in Digos Bridge's Pier 45
Figure 40. Validation points acquisition survey setup 45
Figure 41. LiDAR Ground validation survey along Digos River Basin 46
Figure 42. Manual bathymetric survey in Digos River 47
Figure 43. Bathymetric points gathered from Digos River 47
Figure 44. Digos riverbed centerline profile 48
Figure 45. The location map of Digos HEC-HMS model used for calibration 49
Figure 46. Cross-Section Plot of Digos Bridge 50
Figure 47. Rating Curve at Digos Bridge 2, Aplaya, Digos City 50
Figure 48. Rainfall and outflow data at Digos used for modeling 51
Figure 49. Davao RIDF location relative to Digos River Basin 52
Figure 50. Synthetic storm generated for a 24-hr period rainfall for various return periods 52
Figure 51. Soil Map of Digos River Basin 53
Figure 52. Land Cover Map of Digos River Basin (Source: NAMRIA) 53
Figure 53. Slope map of the Digos River Basin 54
Figure 54. Stream Delineation Map of Digos River Basin 55
Figure 55. The Digos river basin model generated using HEC-HMS 56
Figure 56. River cross-section of Digos River generated through Arcmap HEC GeoRAS tool 57
Figure 57. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro 58
Figure 58. Generated 100-year rain return hazard map from FLO-2D Mapper 58
Figure 59 Generated 100-year rain return flow depth map from FLO-2D Mapper 59
Figure 60. Outflow Hydrograph of Digos produced by the HEC-HMS model compared with observed outflow 60
Figure 61. Outflow hydrograph at Digos Station generated using Davao RIDF simulated in HEC-HMS. 62
Figure 62. Digos Padada-Mainit river (1) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS 63
Figure 63. Digos Padada-Mainit river (2) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS 63
Figure 64. Digos Padada-Mainit river (3) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS 64
Figure 65. Digos Padada-Mainit river (4) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS 64
Figure 66. Digos Padada-Mainit river (5) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS 65
Figure 67. Digos Padada-Mainit river (6) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS 65
Figure 68. Digos Padada-Mainit river (7) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS 66
Figure 69. Digos Padada-Mainit river (8) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS 66

Figure 70. Digos Padada-Mainit river (9) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS.....67
Figure 71. Digos Padada-Mainit river (10) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS.....67
Figure 72. Sample output of Digos RAS Model.....71
Figure 73. 100-year Flood Hazard Map for Digos Floodplain 73
Figure 74. 100-year Flow Depth Map for Digos Floodplain 74
Figure 75. 25-year Flood Hazard Map for Digos Floodplain 75
Figure 76. 25-year Flow Depth Map for Digos Floodplain 76
Figure 77. 5-year Flood Hazard Map for Digos Floodplain 77
Figure 78. 5-year Flood Depth Map for Digos Floodplain.....78
Figure 79. Affected Areas in Bansalan, Davao del Sur during 5-Year Rainfall Return Period 80
Figure 80. Affected Areas in Digos City, Davao del Sur during 5-Year Rainfall Return Period 80
Figure 81. Affected Areas in Digos City, Davao del Sur during 5-Year Rainfall Return Period 81
Figure 82. Affected Areas in Hagonoy, Davao del Sur during 5-Year Rainfall Return Period 84
Figure 83. Affected Areas in Hagonoy, Davao del Sur during 5-Year Rainfall Return Period 84
Figure 84. Affected Areas in Kiblawan, Davao del Sur during 5-Year Rainfall Return Period 85
Figure 85. Affected Areas in Kiblawan, Davao del Sur during 5-Year Rainfall Return Period 85
Figure 86. Affected Areas in Kiblawan, Davao del Sur during 5-Year Rainfall Return Period 88
Figure 87. Affected Areas in Magsaysay, Davao del Sur during 5-Year Rainfall Return Period 89
Figure 88. Affected Areas in Malalag, Davao del Sur during 5-Year Rainfall Return Period 90
Figure 89. Affected Areas in Matanao, Davao del Sur during 5-Year Rainfall Return Period 90
Figure 90. Affected Areas in Matanao, Davao del Sur during 5-Year Rainfall Return Period 92
Figure 91. Affected Areas in Matanao, Davao del Sur during 5-Year Rainfall Return Period 92
Figure 92. Affected Areas in Padada, Davao del Sur during 5-Year Rainfall Return Period 94
Figure 93. Affected Areas in Padada, Davao del Sur during 5-Year Rainfall Return Period 95
Figure 94. Affected Areas in Sta. Cruz, Davao del Sur during 5-Year Rainfall Return Period 96
Figure 95. Affected Areas in Sulop, Davao del Sur during 5-Year Rainfall Return Period.....97
Figure 96. Affected Areas in Sulop, Davao del Sur during 5-Year Rainfall Return Period.....97
Figure 97. Affected Areas in Sulop, Davao del Sur during 5-Year Rainfall Return Period.....98
Figure 98. Affected Areas in Columbio, Sultan Kudarat during 5-Year Rainfall Return Period.....99
Figure 99. Affected Areas in Bansalan, Davao del Sur during 25-Year Rainfall Return Period 100
Figure 100. Affected Areas in Digos City, Davao del Sur during 25-Year Rainfall Return Period 100
Figure 101. Affected Areas in Digos City, Davao del Sur during 25-Year Rainfall Return Period 102
Figure 102. Affected Areas in Hagonoy, Davao del Sur during 25-Year Rainfall Return Period 102
Figure 103. Affected Areas in Hagonoy, Davao del Sur during 25-Year Rainfall Return Period 104
Figure 104. Affected Areas in Kiblawan, Davao del Sur during 5-Year Rainfall Return Period 104
Figure 105. Affected Areas in Kiblawan, Davao del Sur during 5-Year Rainfall Return Period 106
Figure 106. Affected Areas in Kiblawan, Davao del Sur during 5-Year Rainfall Return Period 106
Figure 107. Affected Areas in Magsaysay, Davao del Sur during 25-Year Rainfall Return Period.....108
Figure 108. Affected Areas in Malalag, Davao del Sur during 25-Year Rainfall Return Period.....109
Figure 109. Affected Areas in Matanao, Davao del Sur during 25-Year Rainfall Return Period 110
Figure 110. Affected Areas in Matanao, Davao del Sur during 25-Year Rainfall Return Period 110
Figure 111. Affected Areas in Matanao, Davao del Sur during 25-Year Rainfall Return Period 113
Figure 112. Affected Areas in Padada, Davao del Sur during 25-Year Rainfall Return Period.....114
Figure 113.. Affected Areas in Padada, Davao del Sur during 25-Year Rainfall Return Period.....115
Figure 114. Affected Areas in Santa Cruz, Davao del Sur during 25-Year Rainfall Return Period.....116
Figure 115. Affected Areas in Sulop, Davao del Sur during 25-Year Rainfall Return Period.....117
Figure 116. Affected Areas in Sulop, Davao del Sur during 25-Year Rainfall Return Period.....118

Figure 117. Affected Areas in Sulop, Davao del Sur during 25-Year Rainfall Return Period.....119
Figure 118. Affected Areas in Columbio, Sultan Kudarat during 25-Year Rainfall Return Period.....120
Figure 119. Affected Areas in Bansalan, Davao del Sur during 100-Year Rainfall Return Period 121
Figure 120. Affected Areas in Digos City, Davao del Sur during 100-Year Rainfall Return Period 123
Figure 121. Affected Areas in Digos City, Davao del Sur during 100-Year Rainfall Return Period 123
Figure 122. Affected Areas in Hagonoy, Davao del Sur during 100-Year Rainfall Return Period.....125
Figure 123. Affected Areas in Hagonoy, Davao del Sur during 100-Year Rainfall Return Period.....125
Figure 124. Affected Areas in Kiblawan, Davao del Sur during 100-Year Rainfall Return Period 126
Figure 125. Affected Areas in Kiblawan, Davao del Sur during 100-Year Rainfall Return Period 128
Figure 126. Affected Areas in Kiblawan, Davao del Sur during 100-Year Rainfall Return Period 128
Figure 127. Affected Areas in Magsaysay, Davao del Sur during 100-Year Rainfall Return Period.....130
Figure 128. Affected Areas in Malalag, Davao del Sur during 100-Year Rainfall Return Period.....131
Figure 129. Affected Areas in Matanao, Davao del Sur during 100-Year Rainfall Return Period 131
Figure 130. Affected Areas in Matanao, Davao del Sur during 100-Year Rainfall Return Peri 133
Figure 131. Affected Areas in Matanao, Davao del Sur during 100-Year Rainfall Return Peri 133
Figure 132. Affected Areas in Padada, Davao del Sur during 100-Year Rainfall Return Period.....135
Figure 133. Affected Areas in Padada, Davao del Sur during 100-Year Rainfall Return Period.....136
Figure 134. Affected Areas in Santa Cruz, Davao del Sur during 100-Year Rainfall Return Period.....137
Figure 135. Affected Areas in Sulop, Davao del Sur during 100-Year Rainfall Return Period.....138
Figure 136. Affected Areas in Sulop, Davao del Sur during 100-Year Rainfall Return Period.....139
Figure 137. Affected Areas in Sulop, Davao del Sur during 100-Year Rainfall Return Period.....140
Figure 138. Affected Areas in Columbio, Sultan Kudarat during 100-Year Rainfall Return Period.....141
Figure 139. Flood Validation Points of Digos River Basin.....143
Figure 140. Flood Map Depth vs Actual Flood Depth.....143

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
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UPM	University of the Philippines Mindanao
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND DIGOS RIVER

Enrico C. Paringit, Dr. Eng., Engr. Joseph Acosta, and Engr. Ruth James

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.

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Mindanao (UPM). UPM is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 13 river basins in the Southern Mindanao Region. The university is located in Davao City in the province of Davao del Sur.

1.2 Overview of the Digos River Basin

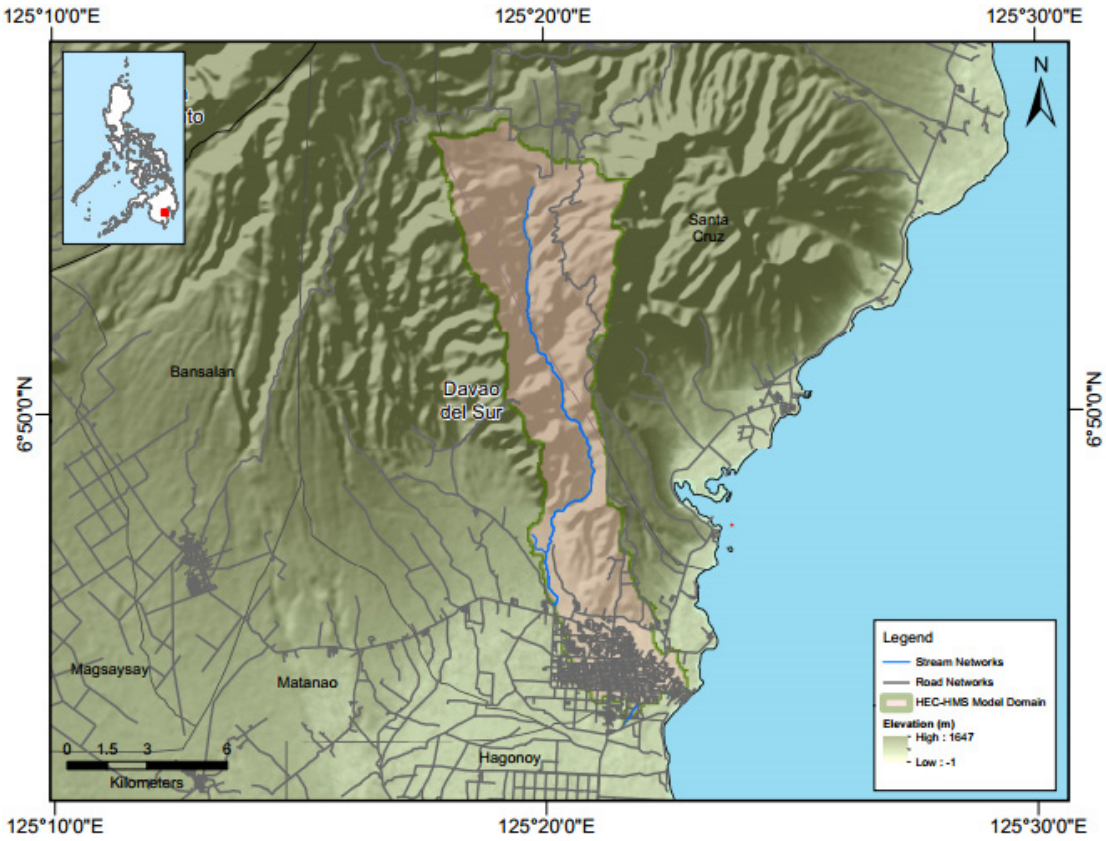


Figure 1. Map of the Digos River Basin (in brown)

The region is blessed with good climate as it experiences Types II and IV climate and lies outside the typhoon belt. Type II climate is characterized by no dry season with very pronounced maximum rainfall. Moreover, Type IV is characterized by more or less evenly distributed rainfall throughout the year. Warm temperature is experienced from February to October while the coolest months start from November up to January. The Region is not directly hit by typhoons and low-pressure systems and is rarely affected by high winds. Generally, climate in Digos falls under the fourth type while wind direction is prevalent from northeast to southwest (Regional Profile - Davao Region, n.d.).

Digos shares common boundaries with the municipalities of Hagonoy in the south, Bansalan in the north and northwest by Siranagan and Miral Creek and with Sta. Cruz in the northeast. It lies on the western shore of the Davao Gulf and southern foothills of Mount Apo on the island of Mindanao, centrally located between the two major cities in Mindanao, Davao City and General Santos City. It has a total land area of 28,710 hectares (70,900 acres) consisting of 26 barangays; nine (9) of which comprise the poblacion or urban center. (Digos, n.d.)
Its land topography ranges from hilly to mountainous in the north-northeast portion and flat and slightly rolling at the coastal barangays, while the urban area and the surrounding barangays in the south portion are generally flat. Digos River is next to the hilly portion and is located in the province of Davao del Sur, Philippines.

Digos is a second class city in and capital of the province Davao del Sur, Philippines. According to the 2015 census, it has a population of 169,393 people, distributed among the twenty-six barangays, namely: Aplaya, Balabag, Binaton, Cogon, Colorado, Dawis, Dulangan, Goma, Igpit, Kiagot, Lungag, Mahayahay, Matti, Kapatagan (Rizal), Ruparan, San Agustin, San Jose (Balutakay), San Miguel (Odaca), San Roque, Sinawilan, Soong, Tiguman, Tres de Mayo, and Poblacion (Zones 1, 2, and 3). (Digos, n.d.)

Agriculture is a major component of Digos City economy. Some 9,330 households or 37% of the total households are dependent on agriculture for their livelihood. Of the total households dependent on agriculture, 91% are engaged in farming and the remaining 9% in fishing. The total area devoted to agriculture covered 8, 944.1 hectares, representing 31% of the total land area of Digos. The more important agricultural crops grown in the area include coconut, sugarcane, mango and banana. Among the agricultural crops, the staple crops rice and corn are the most widely grown (Digos Flood Hazard Modeling and Mapping, 2017).
It is also known for its sweet-juicy 'carabao variety mango,' sold locally and exported abroad, thus being dubbed as the Mango Capital City of the Philippines. It is also considered as The Gate City Of The South. (Digos, n.d.)

Digos River Basin is located in the southeastern part of Mindanao. It is a stream located at the latitude and longitude coordinates of 6.740833 and 125.382222 and within Davao Region and is nearby to Aplaya, Digos Islet and Dawis Beach (Digos River, n.d.). It traverses through the municipality of Santa Cruz down to Digos City in the province of Davao del Sur. It covers an area of 140.15 square kilometres and travels for 33.68 kilometers from its source to its mouth in Davao Gulf with 69 sub basins. The river outlet is between Barangay Aplaya and Barangay Cogon in Digos City (Digos HEC-HMS and HEC-RAS Model Report, 2017).

Located at the southern foothills of Mount Apo, Digos serves as one of the major jump points for mountain climbers preparing to scale the Philippines' highest mountain peak. Mount Apo is home to over 272 bird species, 111 of which are endemic to the area. This includes the critically endangered Philippine Eagle, the country's national bird. Although declared a Natural Park, trash can be seen littered through the climbing trail (Inquirer, 2014).

The water quality of the river conforms to the standards for Class B and C waters. Class B waters are defined as recreational waters for bathing, swimming, skin diving, and those designated for tourism purposes. Class C on the other hand is used as fishery water, non-contact recreational activities such as boating, and as industrial water supply for manufacturing processes. This could be attributed to the wastewater coming from industry, slaughterhouse, residential, hospital, institutional and commercial establishments, agricultural run-off and improper solid waste management (DENR, 2016).

Average values for Color, Temperature, pH, Dissolved Oxygen and Biochemical Oxygen Demand are within the water quality criteria for Class B water as prescribed in Table 1. Total suspended Solids (TSS) level range from 4 mg/L – 80 mg/L. There is no water quality criterion for TSS for Class B water.

Table 1. Digos River Class B Water Quality Assessment

Parameter	Min.	Max.	Ave.	Water Quality Criteria Class B water
Color	1	30	13	No Abnormal Discoloration
Temperature ° C	23	29	26	Max of 3 ° C rise
pH	7.9	8.6	8.2	6.5-8.5
Dissolved Oxygen, mg/L	5.8	7.8	7.3	5.0
BOD (5-day), mg/L	1.1	2.6	1.9	5
Toltal Suspended Solids, mg/L	4	80	29	Not more than 30% increase

Average values for Color, Temperature, pH, Dissolved Oxygen and Biochemical Oxygen Demand are within the water quality criteria for Class C water as prescribed in Table 2. TSS level range from 10 mg/L – 111 mg/L. There is no water quality criterion for TSS for Class C water. Summary of Results is shown below.

Table 2. Digos River Class C Water Quality Assessment

Parameter	Min.	Max.	Ave.	Water Quality Criteria Class B water
Color	1	30	13	No Abnormal Discoloration
Temperature ° C	23	29	26	Max of 3 ° C rise
pH	7.9	8.6	8.2	6.5-8.5
Dissolved Oxygen, mg/L	5.8	7.8	7.3	5.0
BOD (5-day), mg/L	1.1	2.6	1.9	5
Toltal Suspended Solids, mg/L	4	80	29	Not more than 30% increase

WATER QUALITY ASSESSMENT:

Digos River is classified into:

Class B – Sta. 1-2 (Downstream)
Class A - Sta. 3-6 (Upstream)

All samples collected passed the water quality criteria for Color, Temperature, Dissolved Oxygen and Biochemical Oxygen Demand except for pH. However, there was one instance that pH exceeded the maximum pH value of 8.5.

Based on the parameters monitored, the water quality of the river conforms to the standards for Class B & C waters (Water Quality Assessment Report, 2012). According to the classification of water bodies, water in Class B and C rivers cannot be used at all for household purposes. Specifically, Class B rivers are primarily classified for contact recreation like bathing, swimming, skin diving, etc., while Class C waters, also called fishery waters, are intended for the propagation and growth of fish and other aquatic resources (Movido-Aquino, 2003).

CHAPTER 2: LIDAR ACQUISITION OF THE DIGOS FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Grace Acuña,
Engr. Gerome Hipolito, Pauline Joanne G. Arceo, and Engr. Kenneth A. Quisado

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 Digos floodplain in Davao del Sur. These missions were planned for 15 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 3. Figure 2 shows the flight plans and base stations for Digos floodplain.

Table 3. Flight planning parameters for Gemini LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK87A	1000	30	40	100	50	130	5
BLK87B	1000	30	40	100	50	130	5

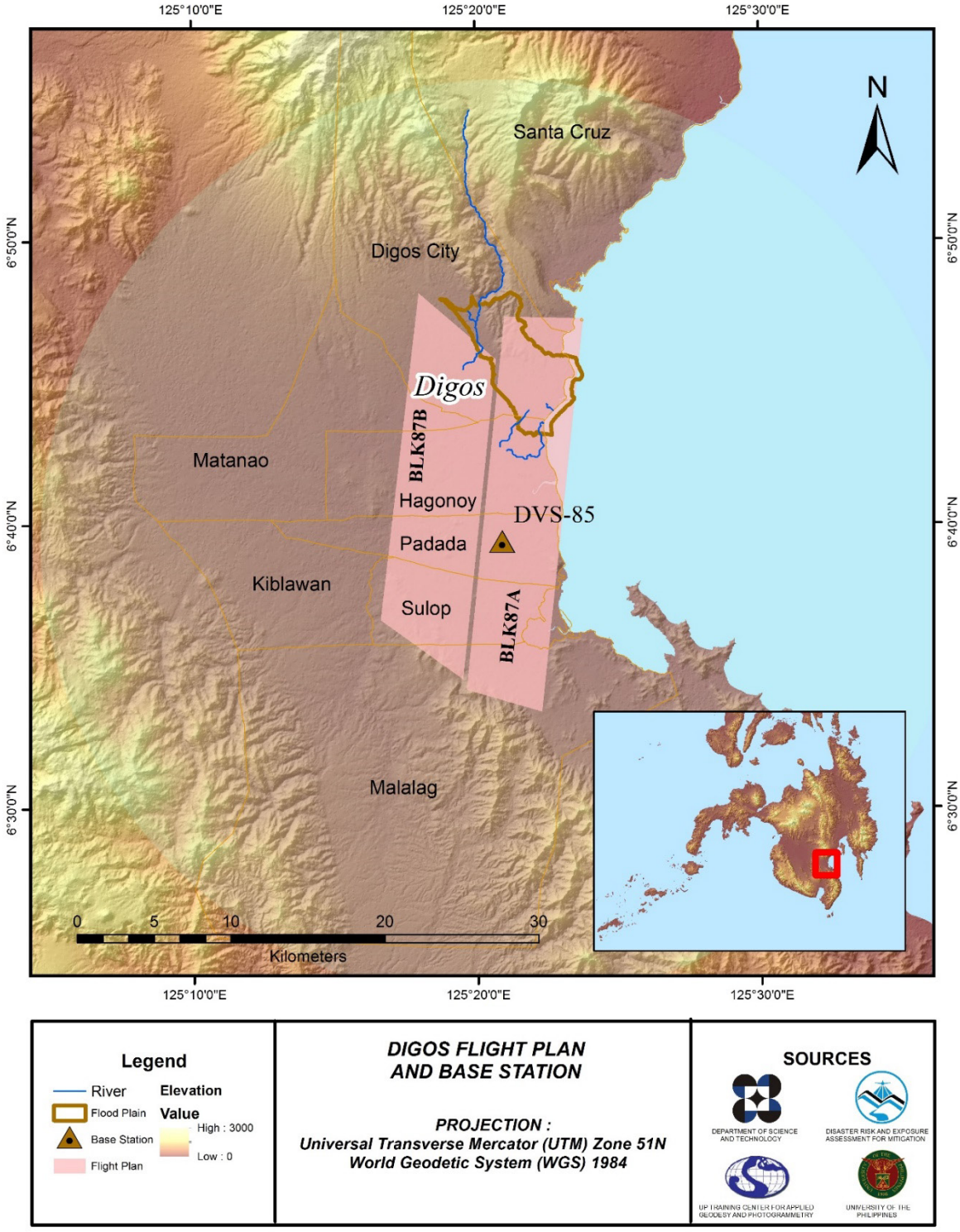


Figure 2. Flight plans and base stations used for Digos Floodplain.

2.2 Ground Base Stations

The project team was able to recover one (1) NAMRIA ground control point: DVS-85 (2nd order accuracy), and BLLM-20 (4th order accuracy). BLLM-20 was then re-processed to obtain coordinates of 2nd order accuracy. The certification for the NAMRIA reference point is found in Annex 2 while the baseline processing report for the re-processed control point is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (July 29 – August 1, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Digos floodplain are shown in Figure 2.
Figure 4 to Figure 7 show the recovered NAMRIA reference points within the area. In addition, Table 4 to Table 7 show the details about the following NAMRIA control stations and established points while Table 8 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

Figure 3. GPS set-up over DVS-85 located inside Mariano Sarona Elementary School, inside the fence of the flagpole (a) and NAMRIA reference point DVS-85 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point DVS-85 used as base station for the LiDAR acquisition

Station Name	DVS-85	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	6°39'26.23973" North 125°20'48.72707" East 6.143 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	538185.160 meters 736134.492 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	6°39'23.20570" North 125°20'54.29136" East 79.008 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	759472.609 meters 736433.274 meters

(a) (b)

Figure 4. GPS set-up over BLLM-20 located inside Mariano Sarona Elementary School, inside the fence of the flagpole (a) and NAMRIA reference point BLLM-20 (b) as recovered by the field team

Table 5. Details of the recovered horizontal control point BLLM-20 used as base station for the LiDAR acquisition with established coordinates

Station Name	BLLM-20	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	6°39'25.99473" North 125°20'48.37658" East 5.656 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	538174.400 meters 736126.960 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	6°39'22.96071" North 125°20'53.94087" East 78.521 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	759461.875 meters 736425.694 meters

Table 6. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
July 29, 2014	7400GC	2BLK87A210A	DVS-85 & BLLM-20
July 31, 2014	7404GC	2BLK87AS212A	DVS-85 & BLLM-20
August 01, 2014	7406GC	2BLK87BC213A	DVS-85 & BLLM-20

2.3 Flight Missions

Three (3) missions were conducted to complete the LiDAR data acquisition in Digos floodplain, for a total of nine hours and twenty one minutes (9+21) of flying time for RP-C9322. All missions were acquired using the Gemini LiDAR system. Table 7 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions for LiDAR data acquisition in Digos 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
JULY 29, 2014	7400GC	126.830	48.522	3.738	44.784	NA	2	5
JULY 31, 2014	7404GC	126.830	169.442	27.629	141.813	NA	3	35
AUGUST 01, 2014	7406GC	118.656	193.272	6.128	187.144	NA	3	41
TOTAL		373.316	411.236	37.495	373.741	NA	9	21

Table 8. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL	Overlap (%)	FOV (Θ)	PRF (KHZ)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
7400GC	1000, 900	30	40, 50	100, 125	50, 40	130	5
7404GC	1000	30	40	100	50	130	5
7406GC	1000	30	40	100	40	130	5

2.4 Survey Coverage

Digos Floodplain is located in the province of Davao Oriental. Municipality of Hagonoy is mostly covered by the survey. The list of municipalities/cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 9. The actual coverage of the LiDAR acquisition for Digos floodplain is presented in Figure 5.

Table 9. List of municipalities and cities surveyed during Digos Floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Davao del Sur	Hagonoy	85.694	70.732	82.54 %
	Digos	226.705	81.801	36.08 %
Total		**312.399**	**152.533**	**48.83%**

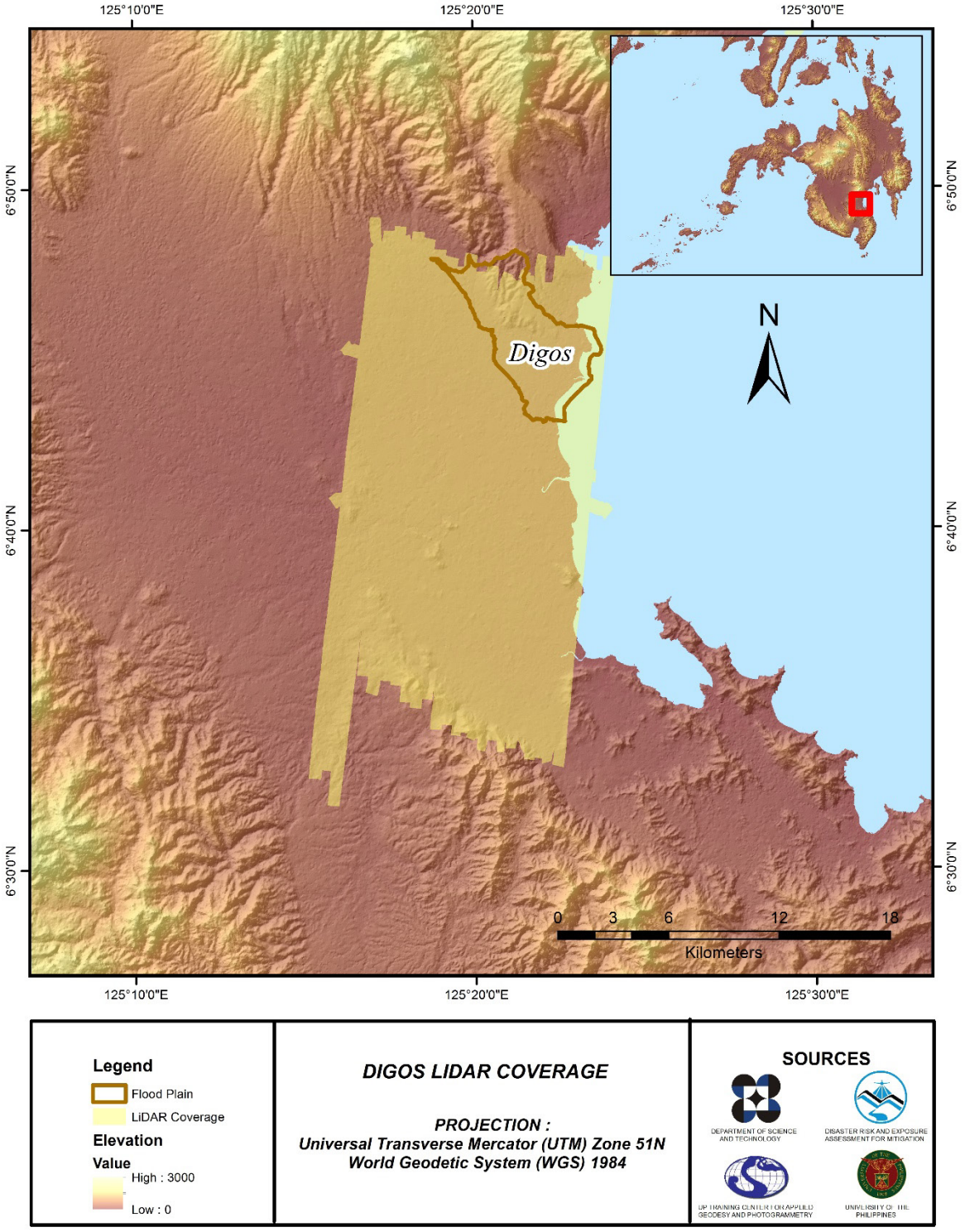


Figure 5. Actual LiDAR survey coverage for Digos floodplain

CHAPTER 3. LIDAR DATA PROCESSING OF THE DIGOS FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Harmond F. Santos , Engr. John Dill P. Macapagal , Engr. Ma. Ailyn L. Olanda, Engr. Velina Angela S. Bemida, Alex John B. Escobido , Engr. Ben Joseph J. Harder, and Engr. Karl Adrian P. Vergara

3.1 Overview of the LiDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component are checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory is done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification is performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds are subject for quality checking to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, are met. The point clouds are then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

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

These processes are summarized in the flowchart shown in Figure 6.

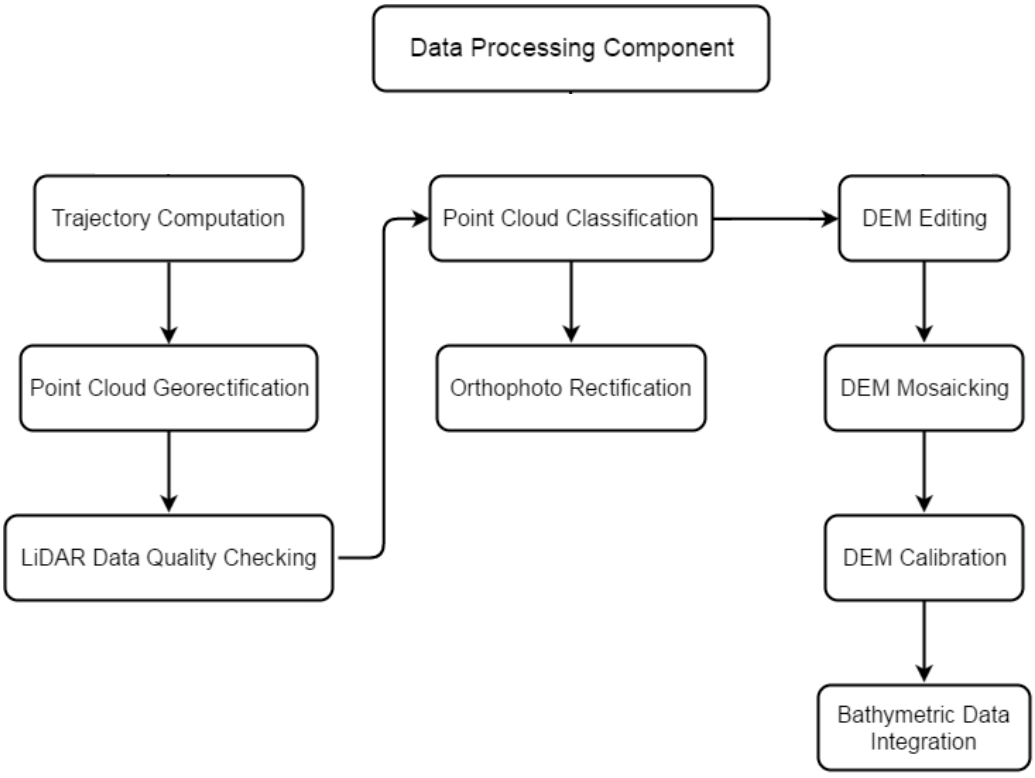


Figure 6. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Digos floodplain can be found in Annex 5. Data Transfer Sheets. Missions flown during the first survey conducted on July 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system over Digos City, Davao Del Sur. The Data Acquisition Component (DAC) transferred a total of 40.24 Gigabytes of Range data, 520 Megabytes of POS data and 13.49 Megabytes of GPS base station data to the data server on August 1, 2014. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Digos was fully transferred on August 12, 2014 as indicated on the Data Transfer Sheets for Digos floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 7406GC, one of the Digos flights, which is the North, East, and Down position RMSE values are shown in Figure 7. 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 February 7, 2015 00:00 AM. The y-axis is the RMSE value for that particular position.

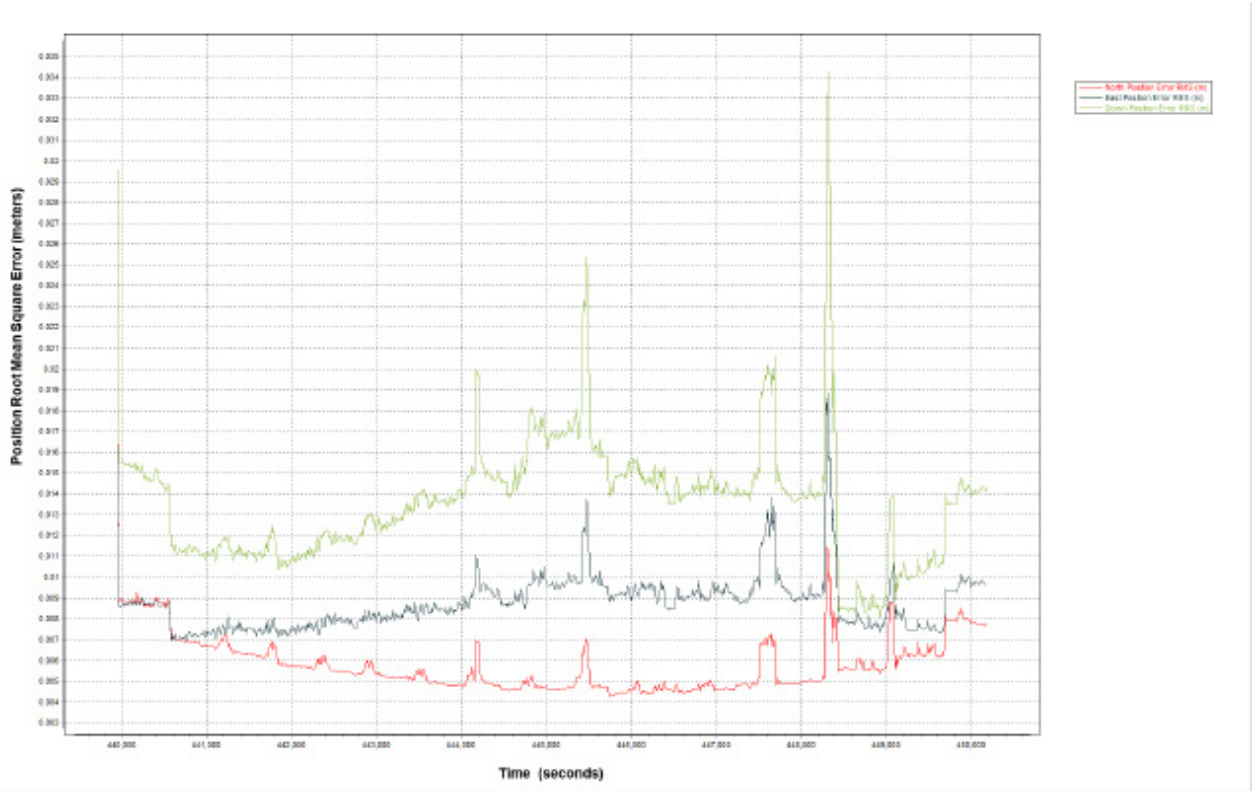


Figure 7. Smoothed Performance Metrics of Digos Flight 7406GC.

The time of flight was from 171750 seconds to 176750 seconds, which corresponds to morning of February 7, 2015. 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 B-2 shows that the North position RMSE peaks at 1.20 centimeters, the East position RMSE peaks at 1.90 centimeters, and the Down position RMSE peaks at 3.40 centimeters, which are within the prescribed accuracies described in the methodology.

Figure 8. Solution Status Parameters of Digos Flight 7406GC.

The Solution Status parameters of flight 7406GC, one of the Digos flights, which indicate 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 8. Most of the time, the number of satellites tracked was between 8 and 12. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Digos flights is shown in Figure 9.

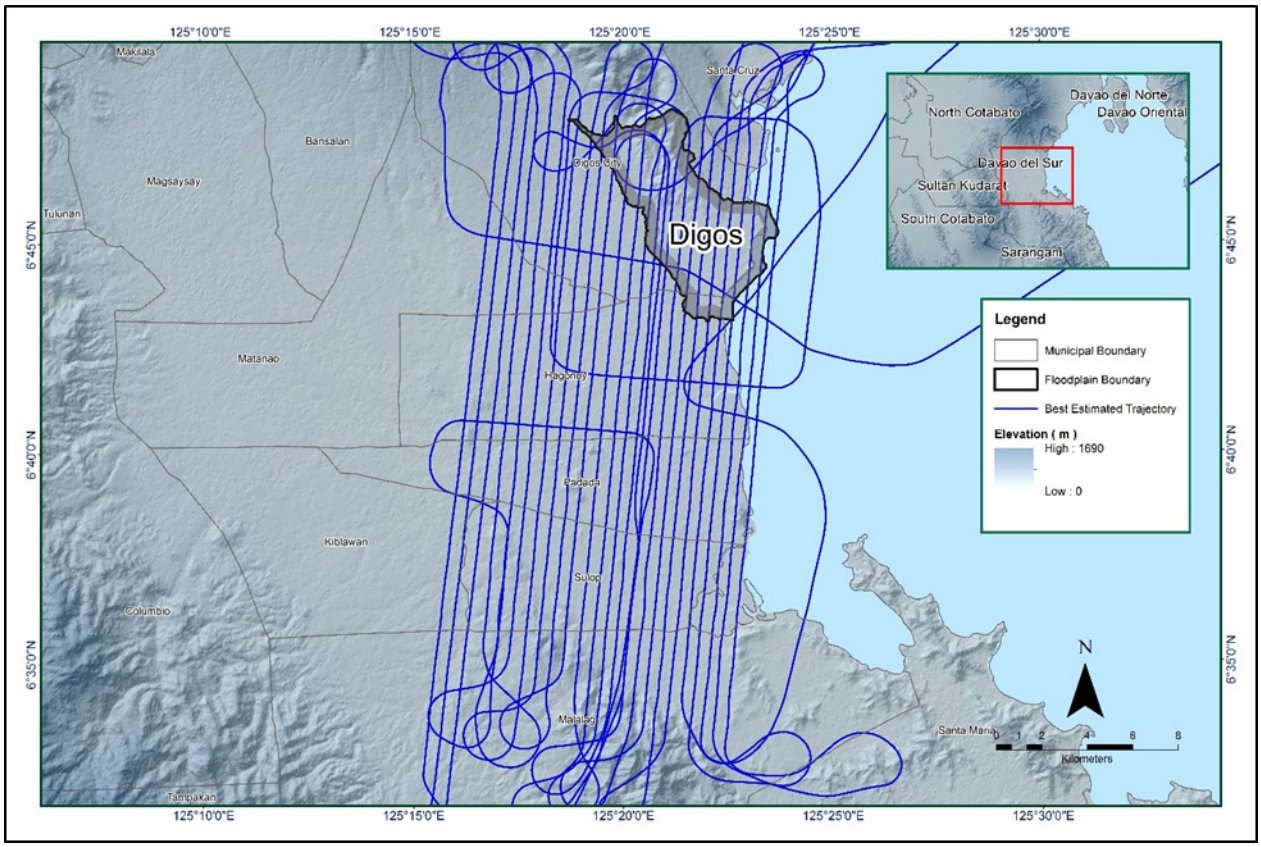


Figure 9. Best estimated trajectory for Digos Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 30 flight lines, with each flight line containing one channel, since the Gemini system contains only one channel. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Digos floodplain are given in Table 10.

Table 10. Self-Calibration Results for Digos Flights

Parameter	Acceptable Value
Boresight Correction stdev (<0.001degrees)	0.000252
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000646
GPS Position Z-correction stdev (<0.01meters)	0.0017

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

3.5 LiDAR Quality Checking

The boundary of the processed LiDAR data is shown in Figure 10. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

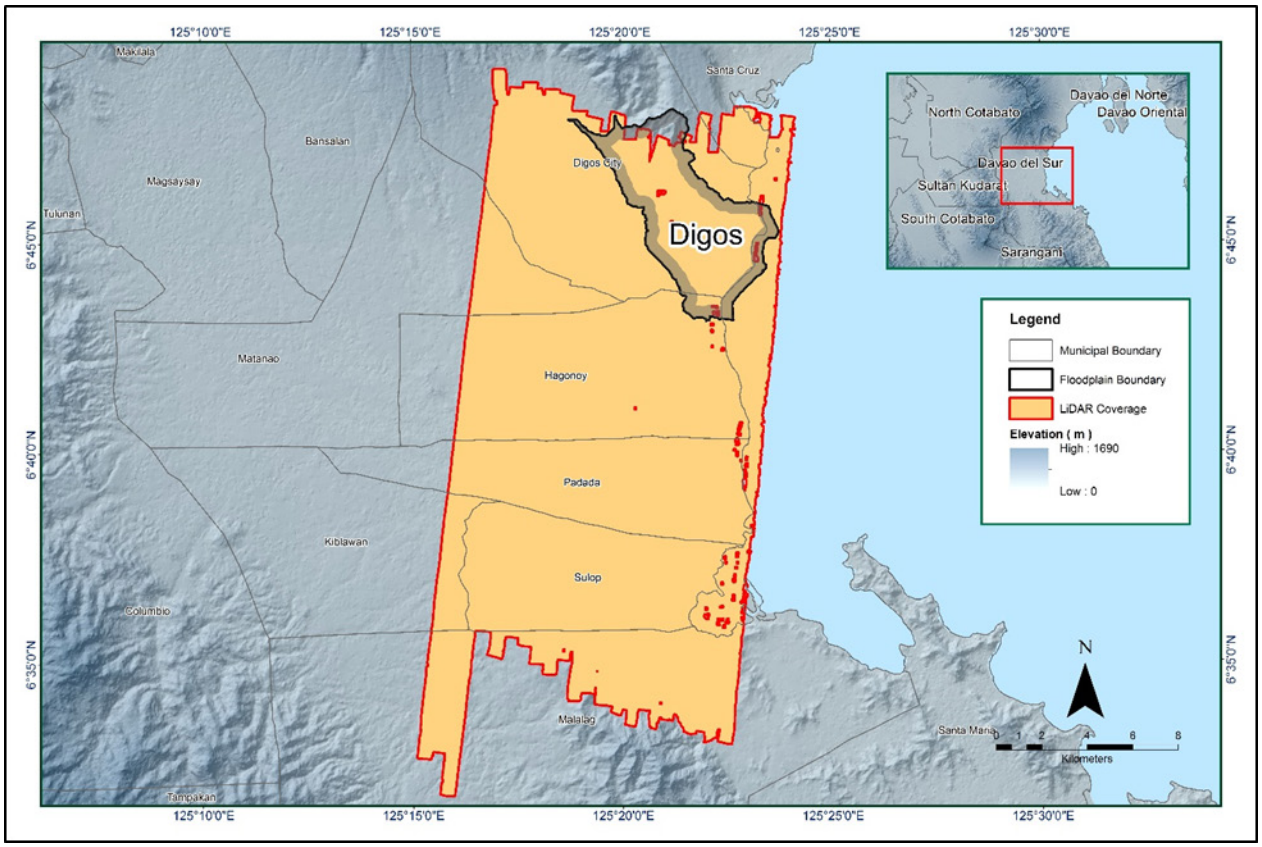


Figure 10. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Digos Floodplain.

The total area covered by the Digos missions is 353.37 sq.km that is comprised of three (3) flight acquisitions grouped and merged into two (2) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Digos Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
DavaoDelSur_Blk87A	7400GC	164.20
	7404GC	
DavaoDelSur_Blk87B	7406GC	189.17
	TOTAL	353.37 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 11. Since the Gemini system employs only 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.

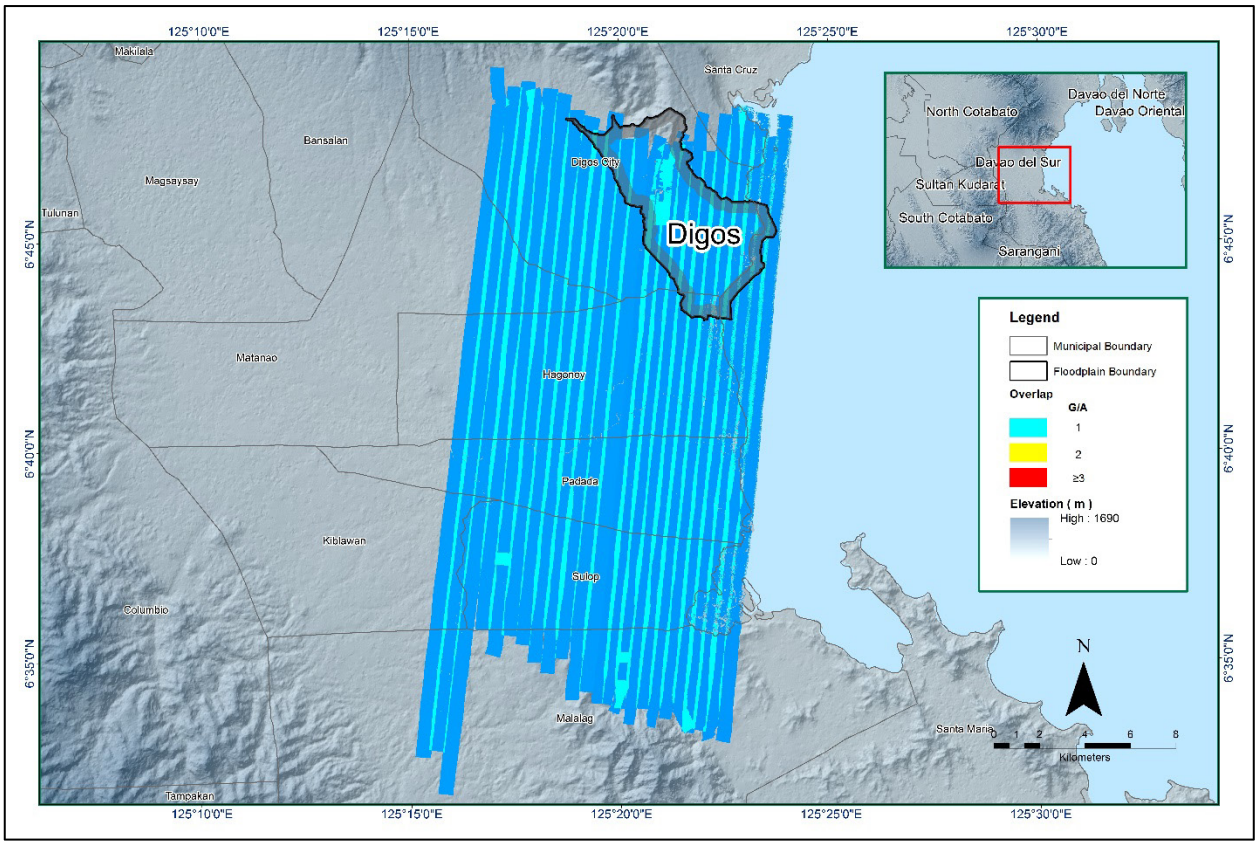


Figure 11. Image of data overlap for Digos Floodplain

The overlap statistics per block for the Digos floodplain can be found in Annex 8. Mission Summary Reports. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 51.19%, 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 12. It was determined that all LiDAR data for Digos floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.82 points per square meter.

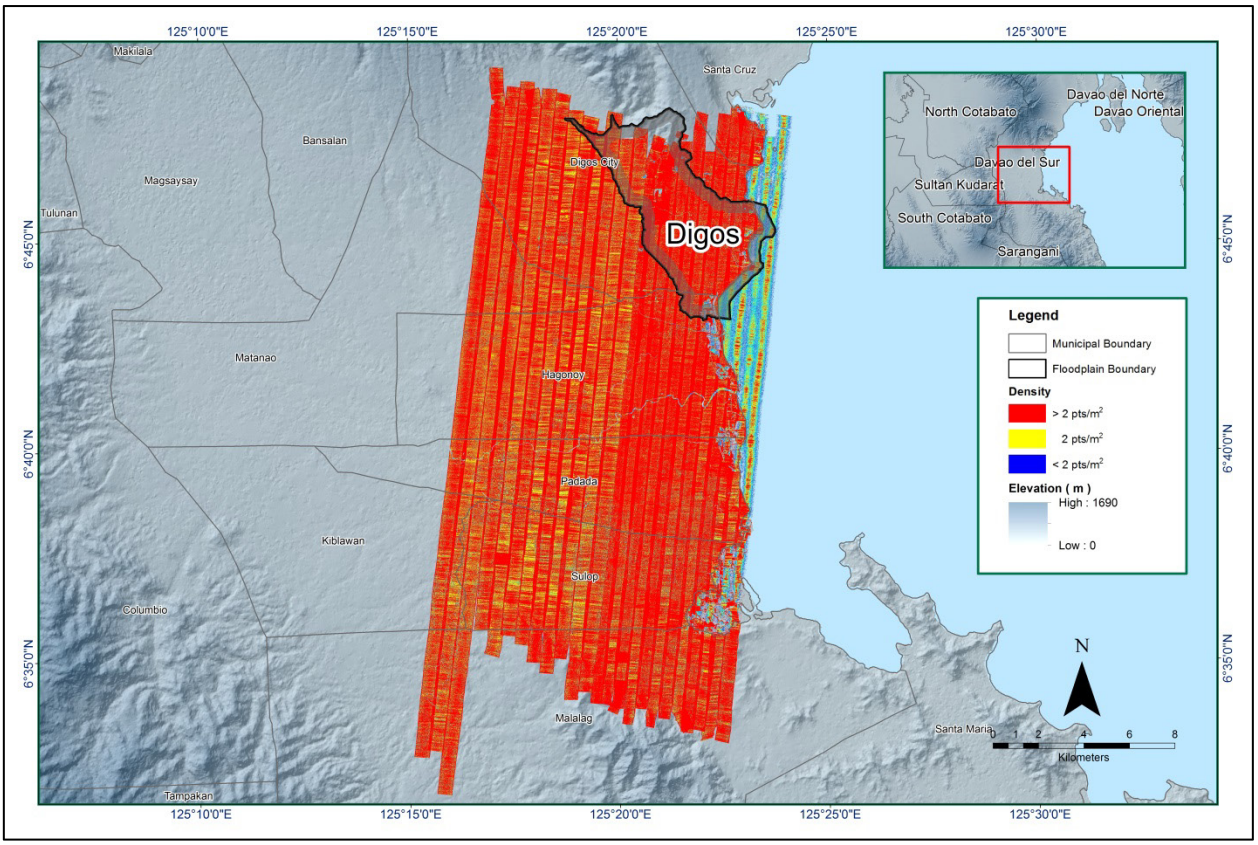


Figure 12. Pulse density map of merged LiDAR data for Digos Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 13. 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.

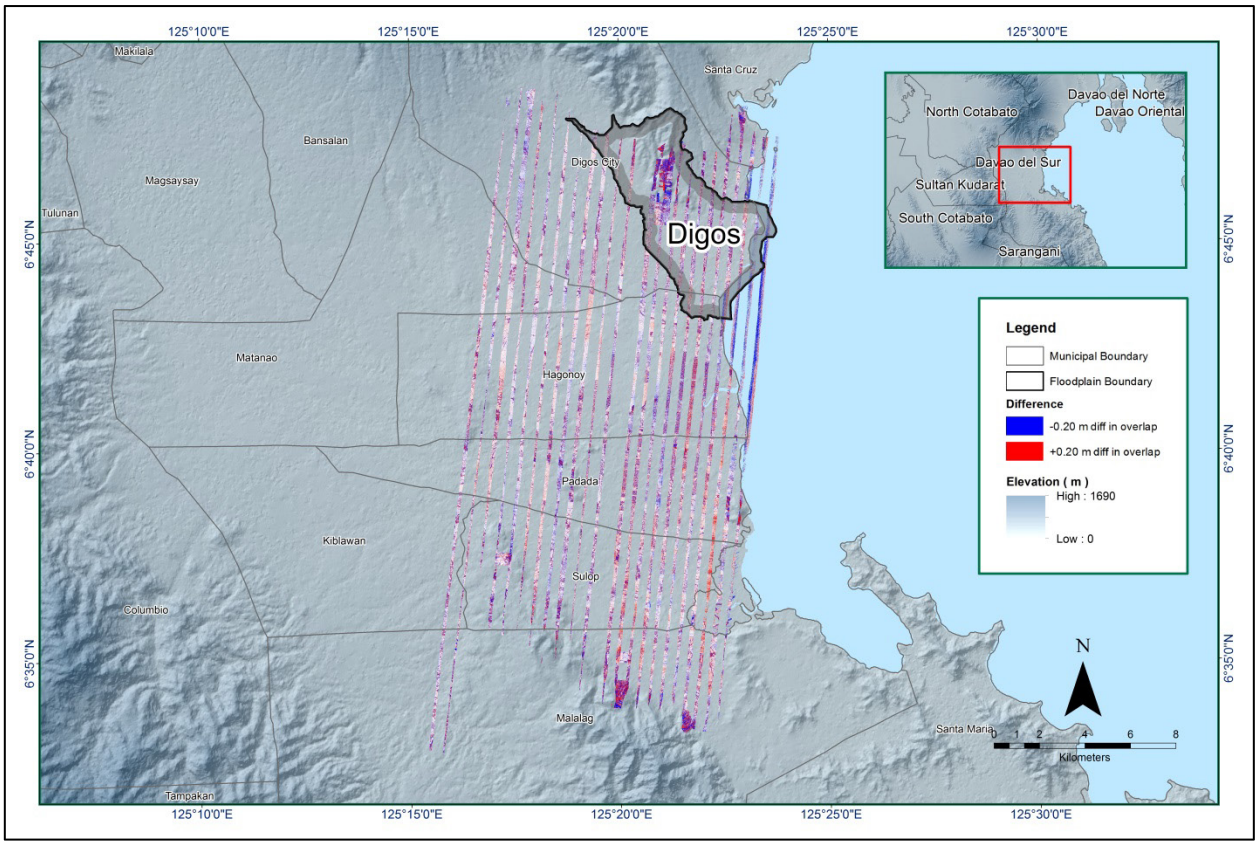


Figure 13. Elevation difference map between flight lines for Digos Floodplain.

A screen capture of the processed LAS data from a Digos flight 7406GC loaded in QT Modeler is shown in Figure 14 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.

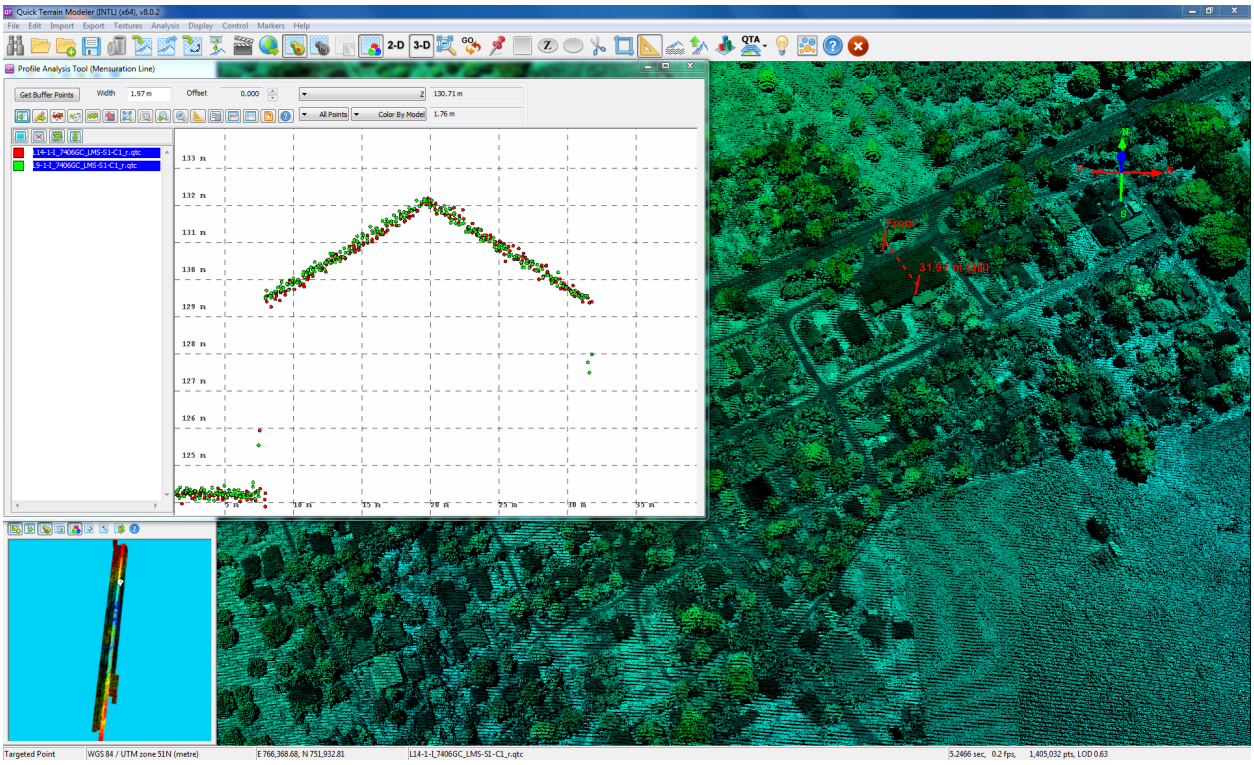


Figure 14. Quality checking for a Digos flight 7406GC using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Digos classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	142,479,850
Low Vegetation	159,869,354
Medium Vegetation	236,241,132
High Vegetation	402,003,963
Building	13,034,767

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Digos floodplain is shown in Figure 15. A total of 446 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 565.04 meters and 68.87 meters respectively.

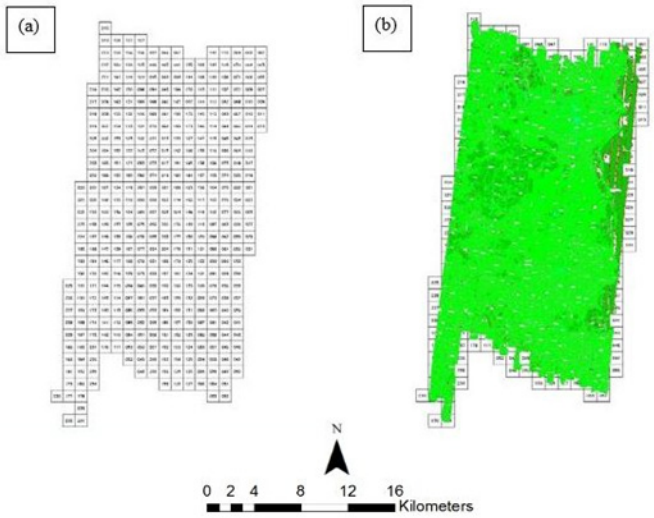


Figure 15. Tiles for Digos floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 16. 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.

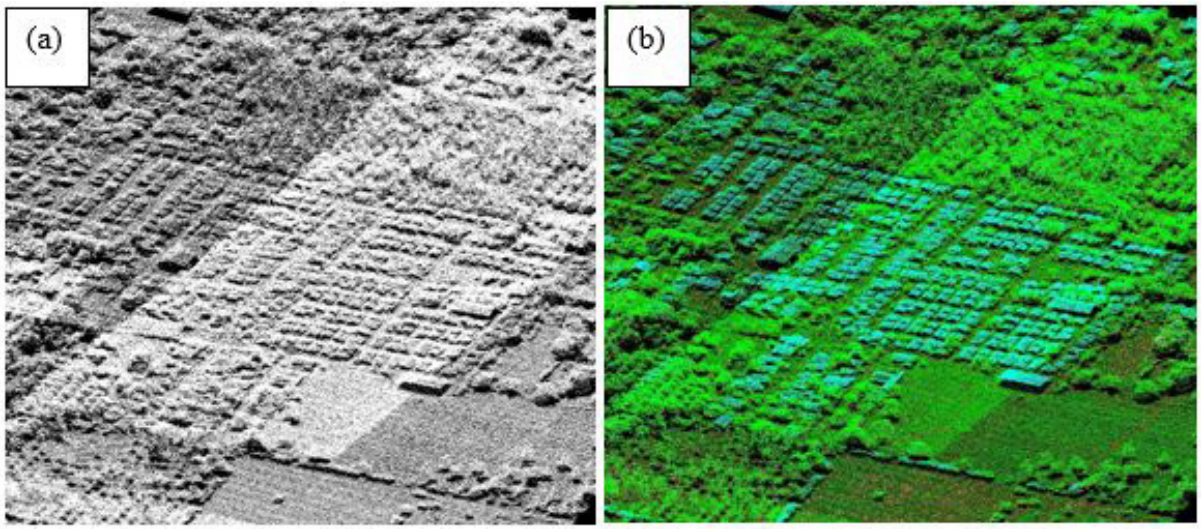


Figure 16. Point cloud before (a) and after (b) classification

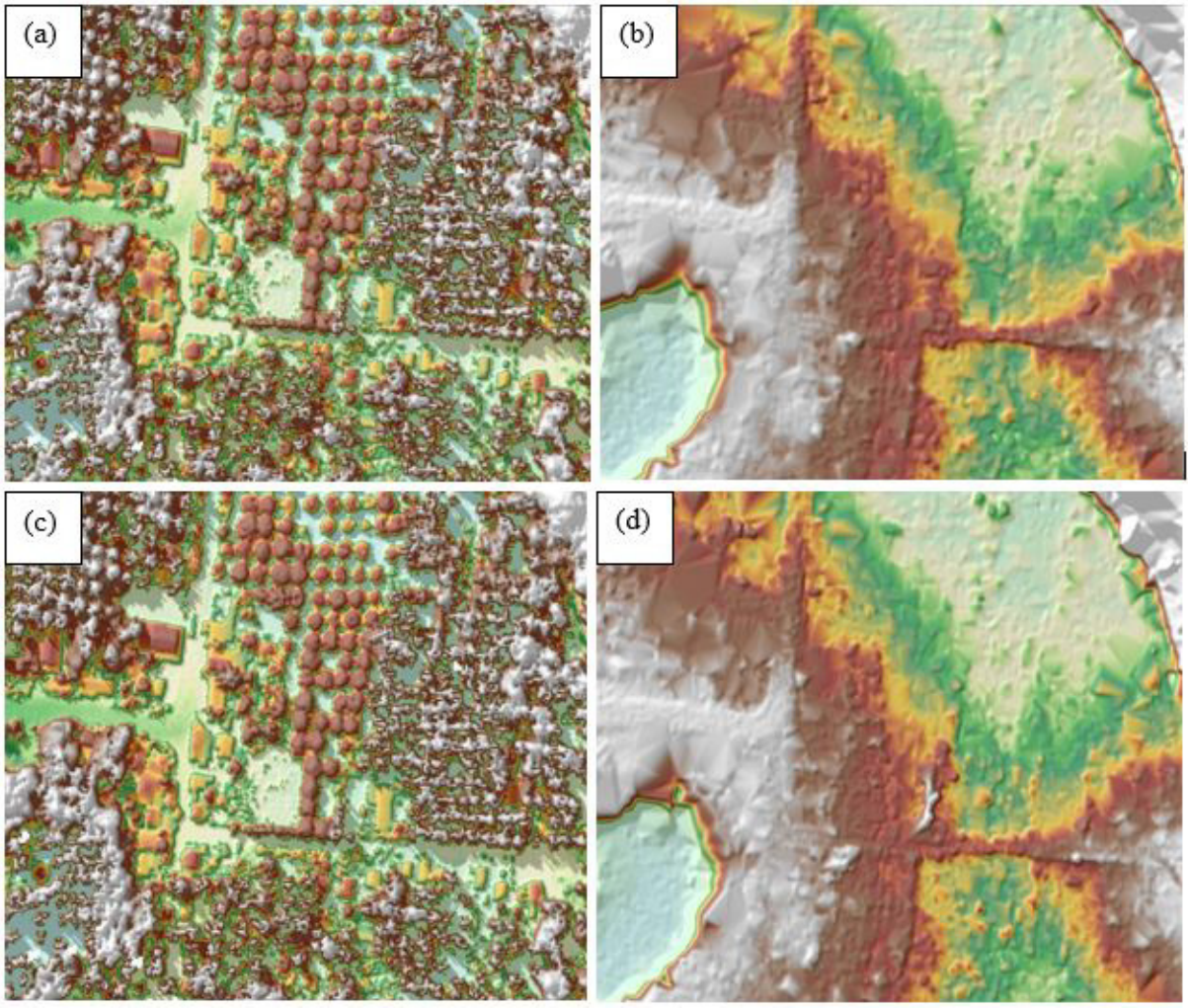


Figure 17. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Digos Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Digos floodplain.

3.8 DEM Editing and Hydro-Correction

Two (2) mission blocks were processed for Digos flood plain. These blocks are composed of Davao blocks with a total area of 353.37 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
DavaoDelSur_Blk87A	164.20
DavaoDelSur_Blk87B	189.17
TOTAL	353.37 SQ.KM

Portions of DTM before and after manual editing are shown in Figure 18. The building that is still present in the DTM after classification (Figure 18a) and has to be removed through manual editing (Figure 18b).

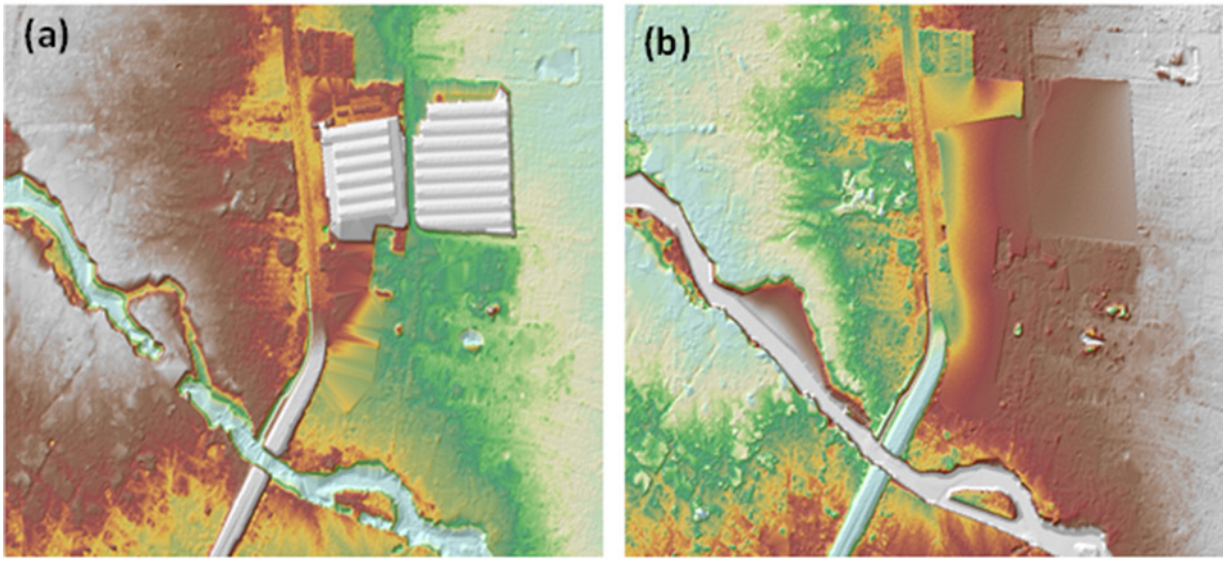


Figure 18. Portions in the DTM of Digos Floodplain – a building before (a) and after (b) manual editing

3.9 Mosaicking of Blocks

DavaoDelSur_Blk87A was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 14 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Digos floodplain is shown in Figure 19. It can be seen that the entire Digos floodplain is 92.70% covered by LiDAR data.

Table 14. Shift Values of each LiDAR Block of Digos Floodplain

Mission Blocks	Shift Values (meters)		
	X	Y	Z
DavaoDelSur_Blk87A	0.00	0.00	-0.80
DavaoDelSur_Blk87B	0.00	0.00	0.00

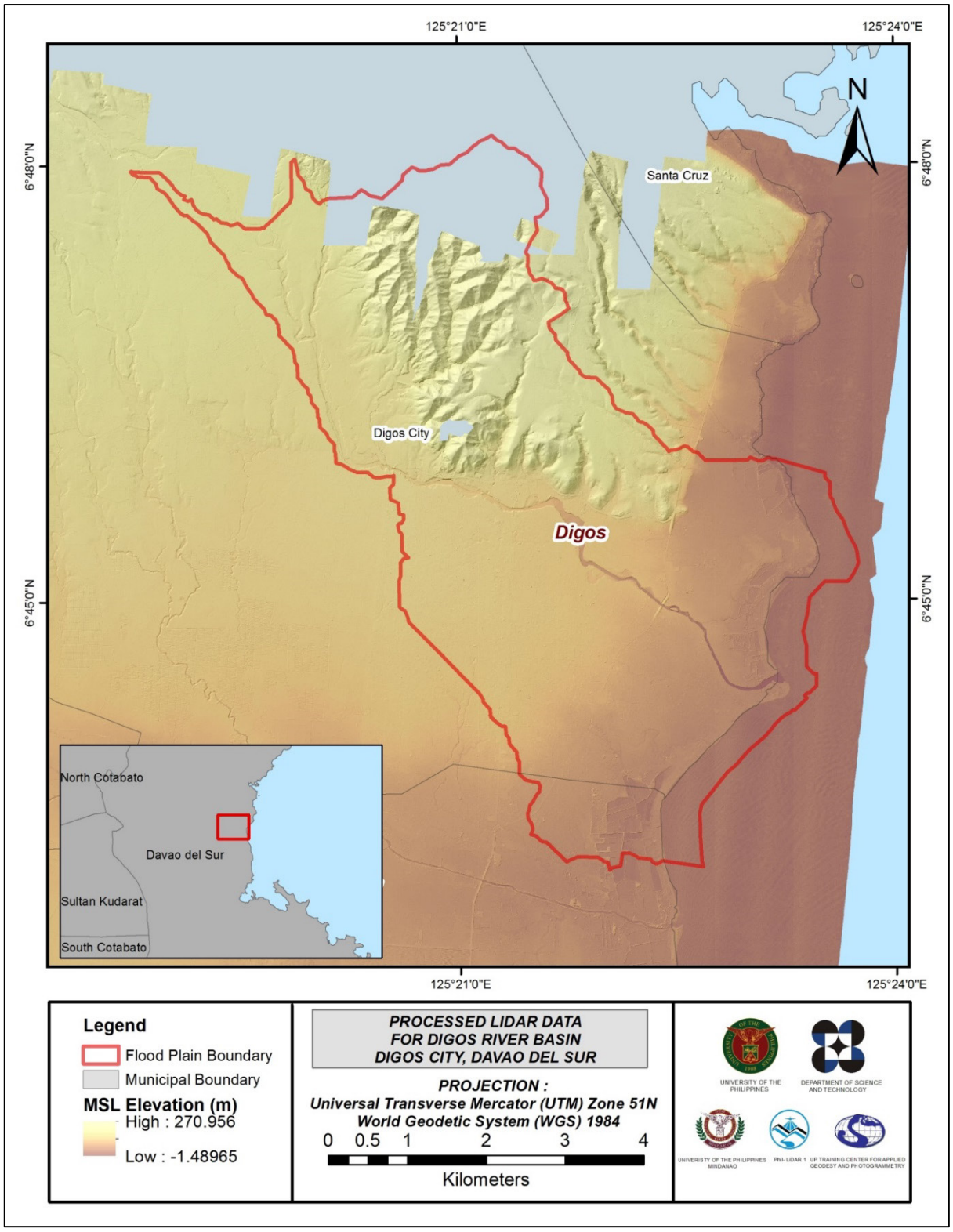


Figure 19. Map of Processed LiDAR Data for Digos Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Digos to collect points with which the LiDAR dataset is validated is shown in Figure 20. A total of 21,221 survey points were used for calibration and validation of Digos LiDAR data. Random selection of 80% of the survey points, resulting to 16,977 points, were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 21. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the

LiDAR DTM and calibration elevation values is 0.20 meters with a standard deviation of 0.12 meters. Calibration of Digos LiDAR data was done by adding the height difference value, 0.20 meters, to Digos mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

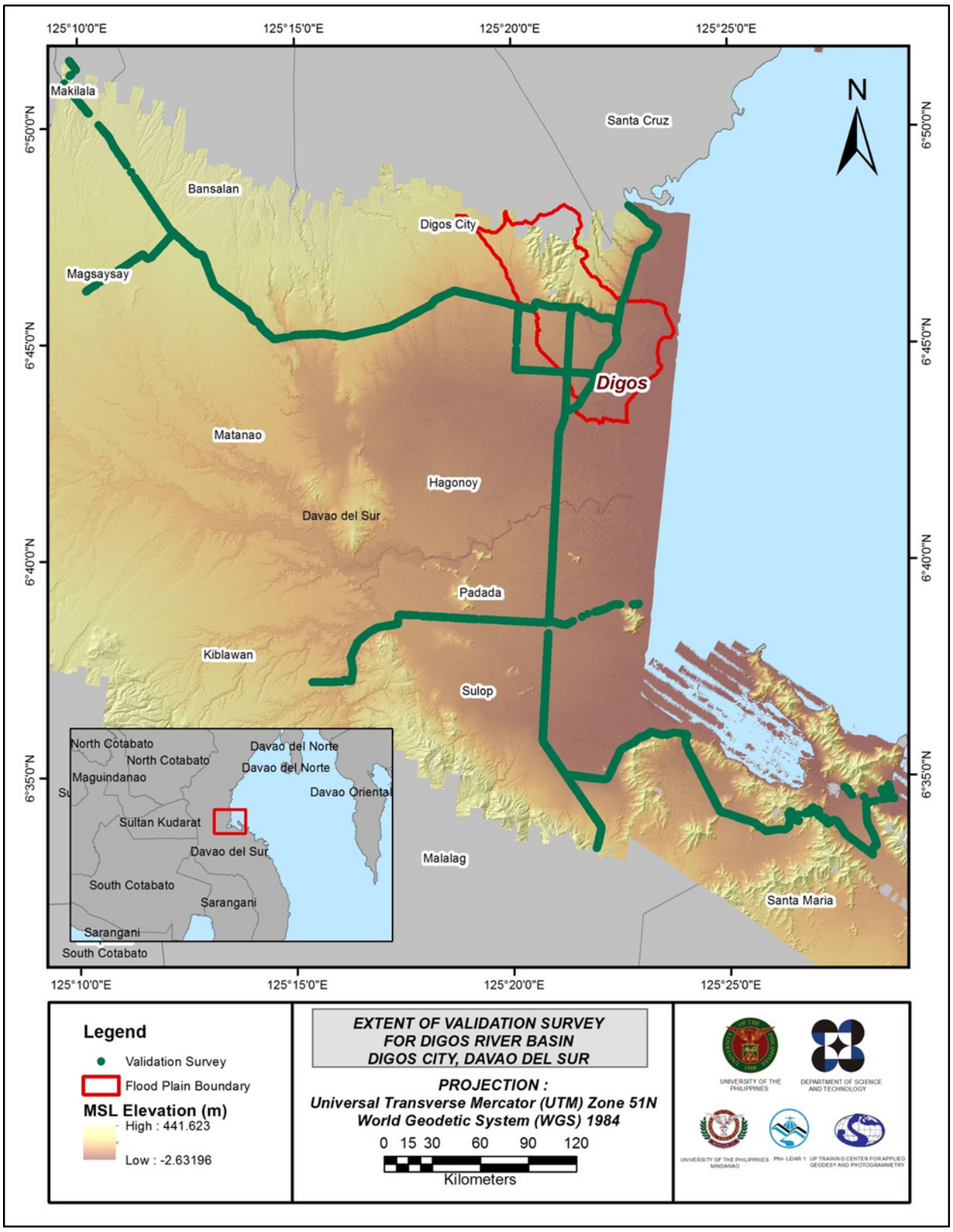


Figure 20. Map of Digos Floodplain with validation survey points in green

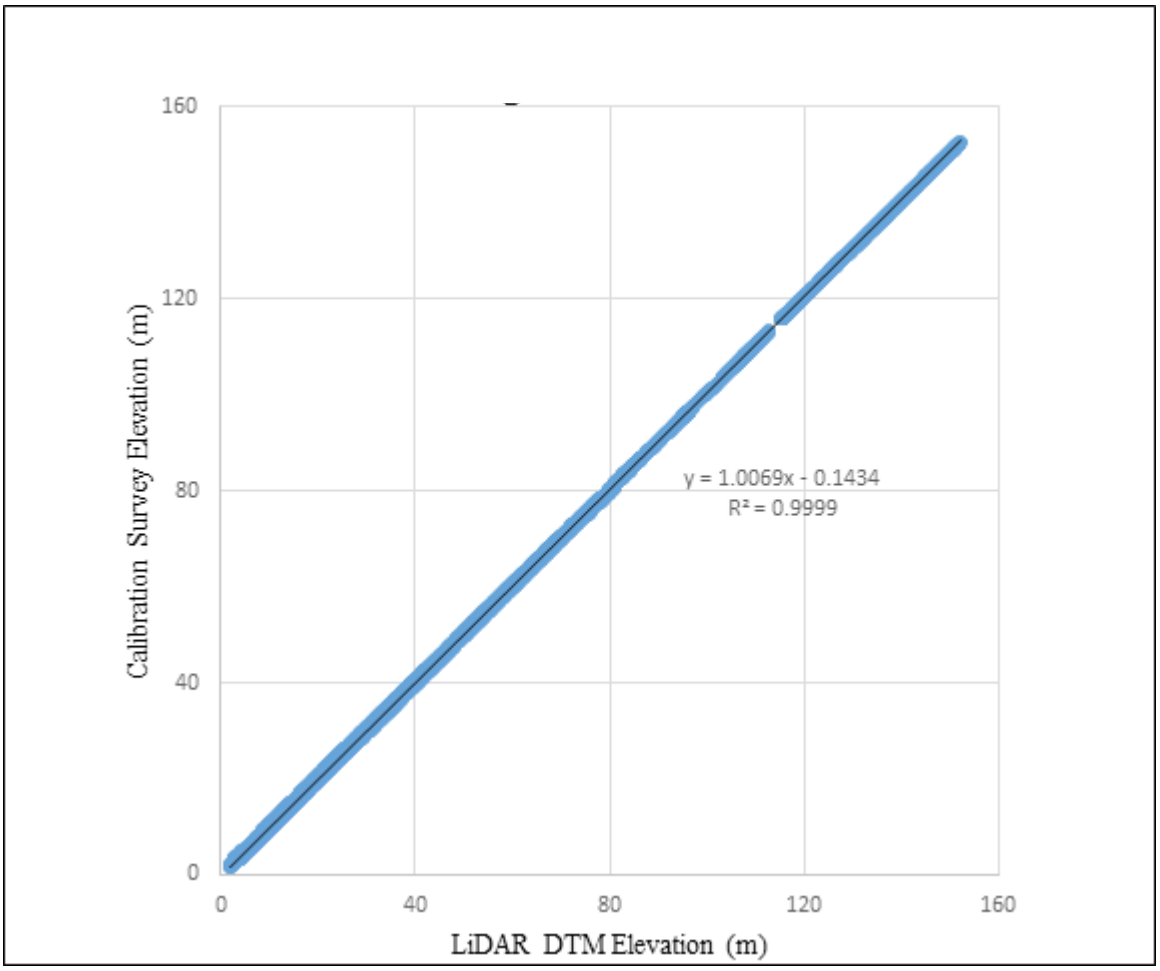


Figure 21. Correlation plot between calibration survey points and LiDAR data

Table 15. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.20
Standard Deviation	0.12
Average	0.16
Minimum	-0.07
Maximum	0.40

The remaining 20% of the total survey points, resulting to 4,244 points, were used for the validation of calibrated Digos DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 22. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.21 meters with a standard deviation of 0.13 meters, as shown in Table 16.

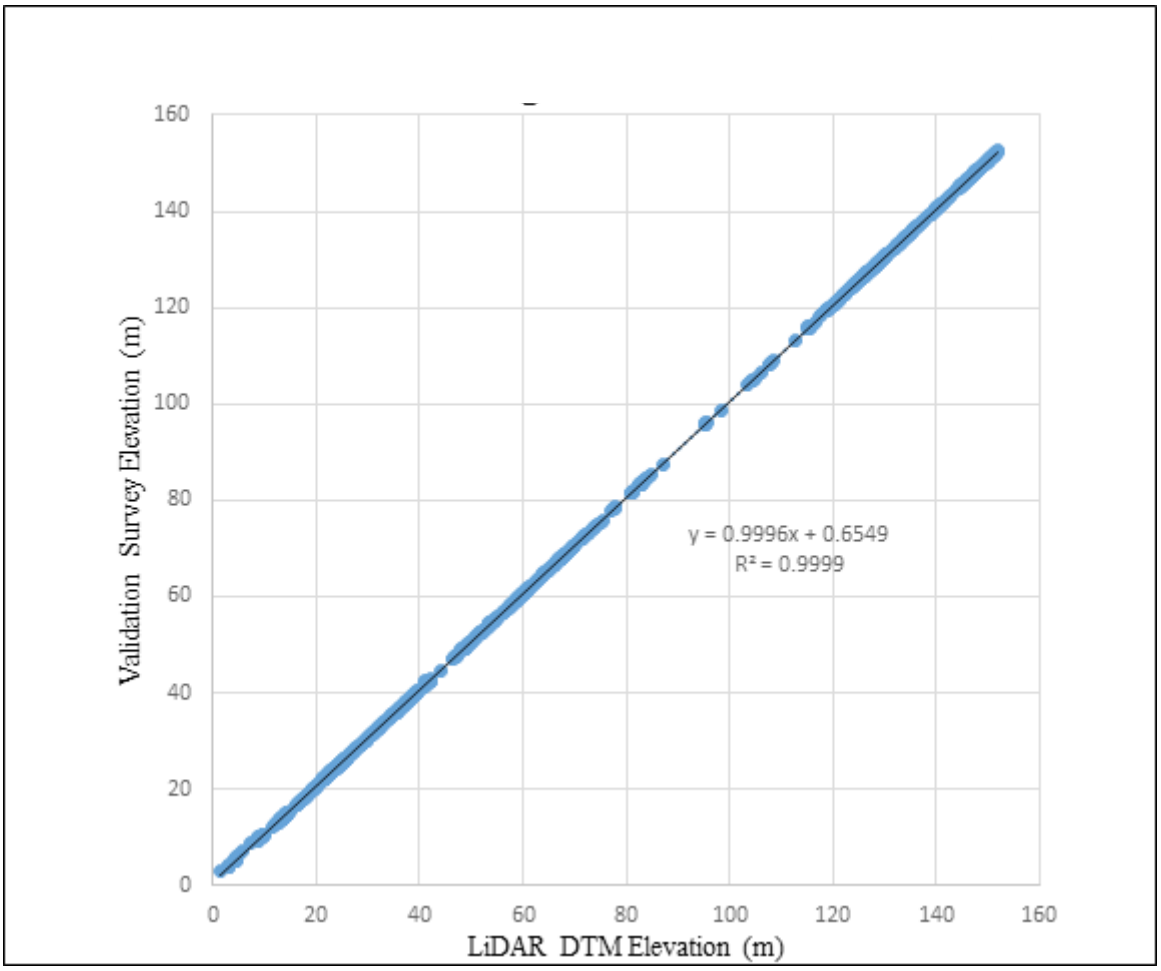


Figure 22. Correlation plot between validation survey points and LiDAR data

Table 16. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.21
Standard Deviation	0.13
Average	0.16
Minimum	-0.10
Maximum	0.42

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline and cross-section data was available for Digos with 1,459 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.49 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Digos integrated

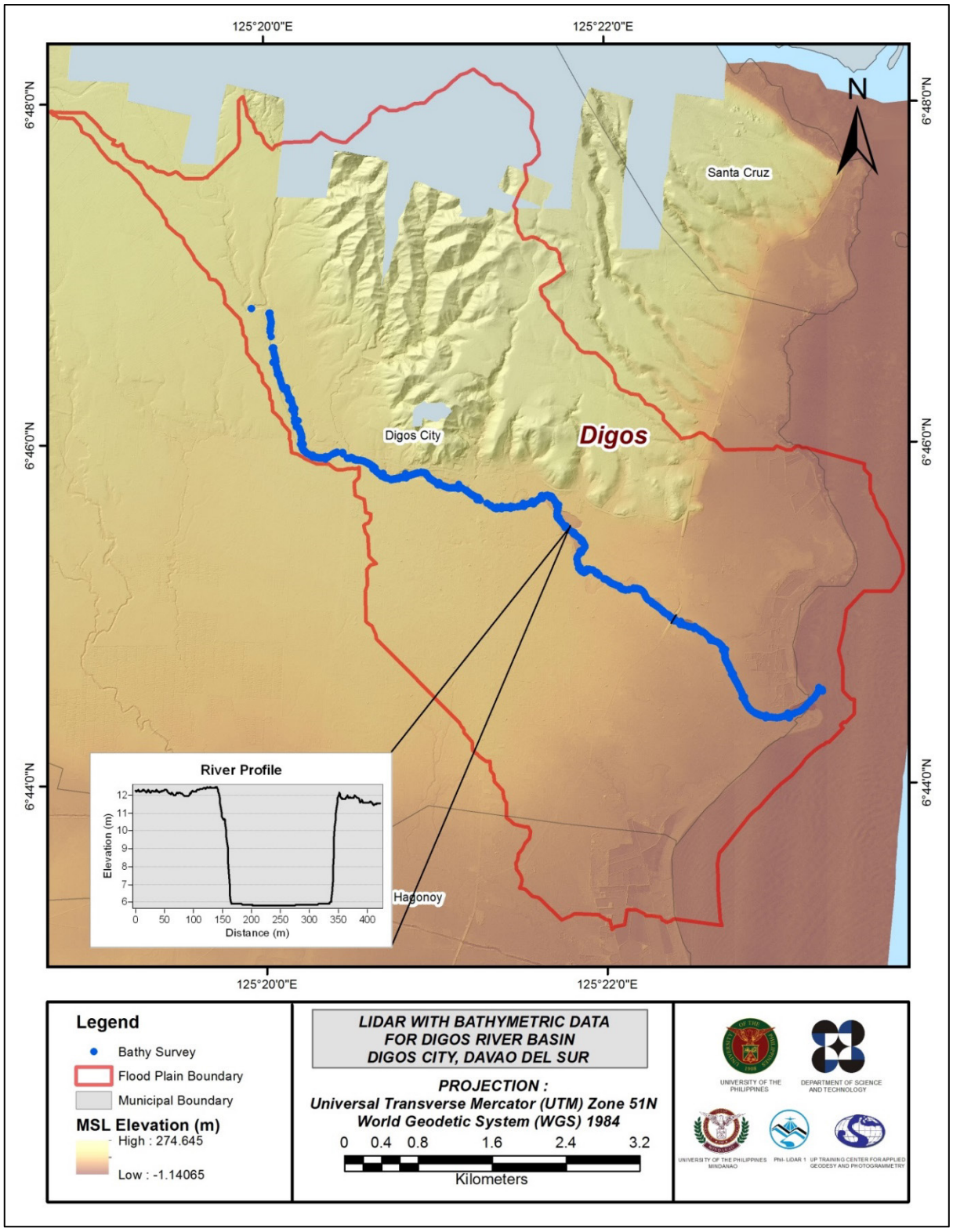


Figure 23. Map of Digos Flood Plain with bathymetric survey points shown in blue

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Digos floodplain, including its 200 m buffer, has a total area of 42.06 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 3295 building features, are considered for QC. Figure 24 shows the QC blocks for Digos floodplain.

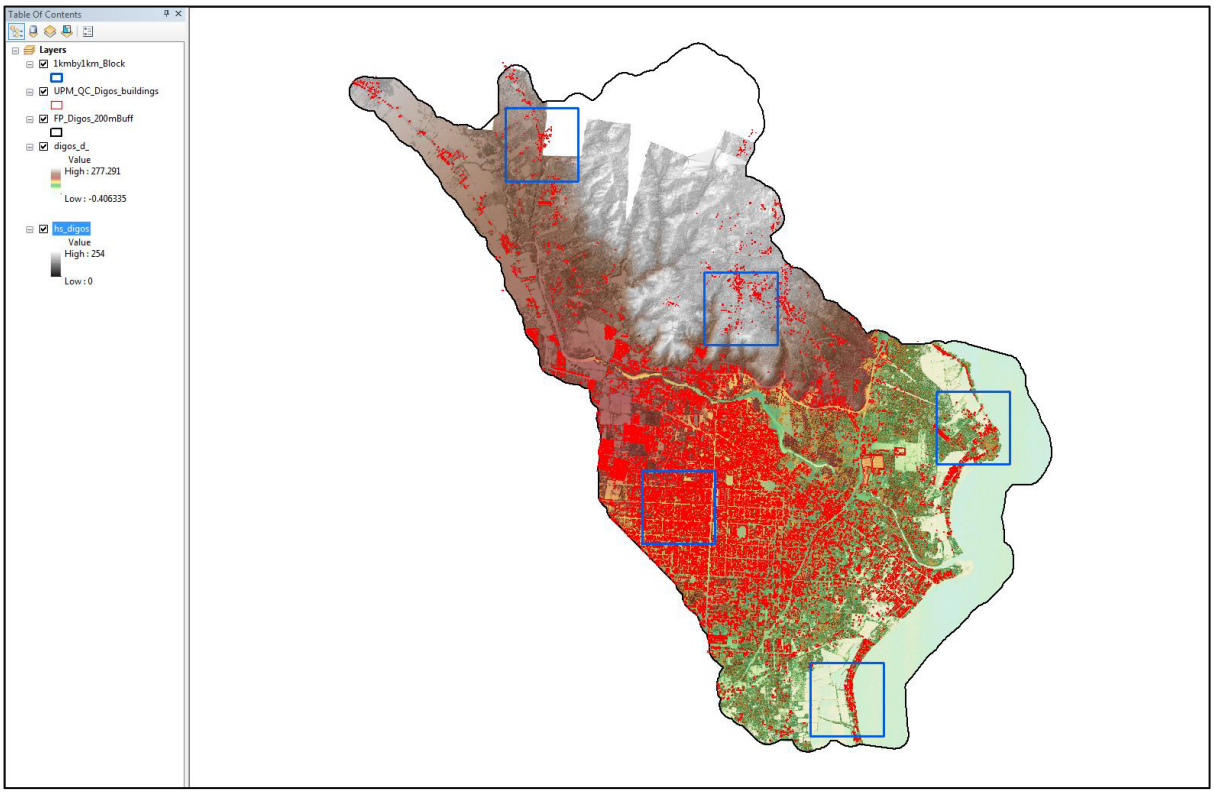


Figure 24. QC blocks for Digos building features

Quality checking of Digos building features resulted in the ratings shown in Table 17.

Table 17. Quality Checking Ratings for Digos Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
DIGOS	98.17	99.48	96.48	PASSED

3.12.2 Height Extraction

Height extraction was done for 23,882 building features in Digos floodplain. Of these building features, 744 was filtered out after height extraction, resulting to 23,138 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 11.99 m.

3.12.3 Feature Attribution

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

The courtesy calls and project presentations were done on January 13 - 15, 2016. Barangay Health Workers (BHWs) were requested and hired to guide the University of the Philippines Mindanao Phil-LiDAR1 field enumerators during validation. The field work activity was conducted from January 25 to February 4, 2016. The local hires deployed by the barangay captains were given a brief orientation by the field enumerators before the actual field work. Some of the personnel volunteered to use their own motorcycle vehicles

during the validation proper. The team surveyed the fourteen (14) barangays covered by the floodplain namely Aplaya, Cogon, Sinawilan, Zone 1, Zone 2, Tres de Mayo, Zone 3, Dawis, San Jose, Balutakay, Kiagot, Dulangan, Ruparan and San Miguel, Digos City.

One of the concerns of the team during field validation was during the field validation include political concerns pertaining to boundary issues among barangays which made the local guides reluctant to cross barangay boundaries with the team. It was also highlighted during the courtesy call that the Balutakay River affects the southern part of Digos City when water rises due to excessive rain.

Table 18 summarizes the number of building features per type. On the other hand, Table 19 shows the total length of each road type, while Table 20 shows the number of water features extracted per type.

Table 18. Building Features Extracted for Digos Floodplain

Facility Type	No. of Features
Residential	21,023
School	307
Market	54
Agricultural/Agro-Industrial Facilities	96
Medical Institutions	90
Barangay Hall	19
Military Institution	3
Sports Center/Gymnasium/Covered Court	38
Telecommunication Facilities	7
Transport Terminal	4
Warehouse	43
Power Plant/Substation	40
NGO/CSO Offices	14
Police Station	3
Water Supply/Sewerage	7
Religious Institutions	202
Bank	20
Factory	18
Gas Station	31
Fire Station	2
Other Government Offices	84
Other Commercial Establishments	1,033
TOTAL	23,138

Table 19. Total Length of Extracted Roads for Digos Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Digos	165.81	17.33	3.51	10.88	0.00	197.52

Table 20. Number of Extracted Water Bodies for Digos Floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Digos	1	2	1		74	78

A total of 4 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 25 shows the Digital Surface Model (DSM) of Digos floodplain overlaid with its ground features.

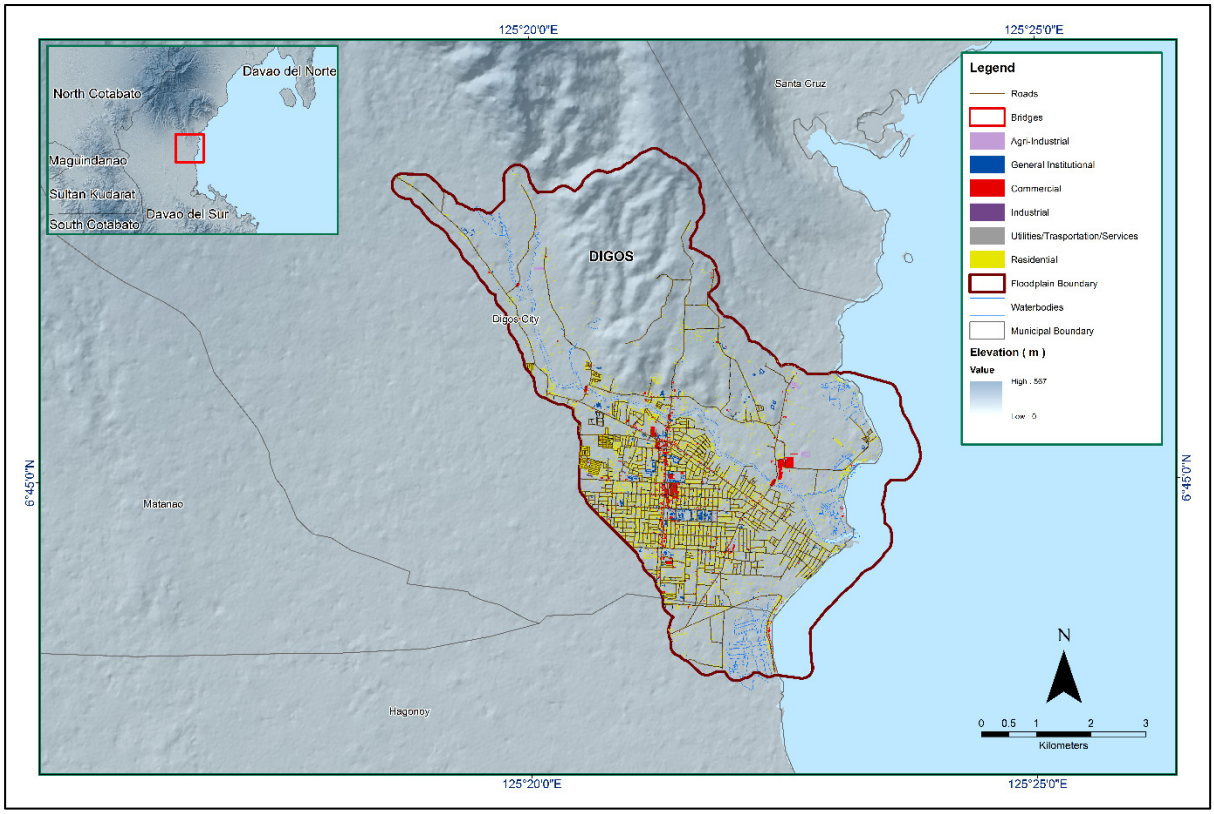


Figure 25. Extracted features for Digos floodplain

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

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

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

Digos River Basin in the Eastern area of Davao Del Sur encompasses the Municipality of Santa Cruz and has a catchment area of approximately 87.135 km2 according to the Flood Modelling Component. The basin has a run-off amount of approximately 350 MCM according to the DENR-RCBO. The area in the vicinity of the Digos River Basin, the Digos City is classified to be highly susceptible to landslide and flooding based from the 2007 Mines and Geosciences Bureau's (MGB) Geohazard Maps.

Its main stem, Digos River channel has an estimated length of 9 km, is among the fourteen (14) river systems in Davao Del as shown in Figure 26. It is bounded by Brgy. Ruparan in the North; Digos City and Brgy. Tres de Mayo in the West; Bry. Balutakay in the South; and the Davao Gulf in the East. Its water, according to its beneficial use is categorized as Class C by the Department of Environmental Management. Its uses are for Fishery Water for the propagation and growth of fish and other aquatic resources; Recreational Water Class II such as Boatings; and Industrial Water Supply Class I for manufacturing processes after treatment. Davao del Sur has a total population of 574,910 based on the 2010 NSO census. The province suffered flooding due to massive rain produced by Typhoon Pablo last December 4, 2012 which is also considered as the strongest storm to hit Mindanao in two decades according to PAG-ASA. Typhoon Pablo also known by its international name Typhoon Bopha, put Mindanao under the state of calamity. The typhoon also resulted to power outrage and destruction of properties of the community.

In line with this, a field survey in Digos River on June 28 to July 12, 2015 with the following scope of work: reconnaissance survey to determine the viability of traversing the planned routes for bathymetric survey; courtesy call to LGU Digos City; control survey for the establishment of control point UP-DIG at Digos bridge approach occupied as base station for GNSS surveys and cross-section, bridge-as-built and water level marking in MSL of Digos Bridge piers; LiDAR acquired ground validation survey with estimated distance of 84.5 km; and bathymetric survey of Digos River covering the areas of Brgy. Tres de Mayo, Brgy. Zone 2, Canos Bridge, Digos Bridge and Brgy. Aplaya with an approximate length of 9 km utilizing GNSS PPK survey technique. The survey extent is shown in Figure 26.

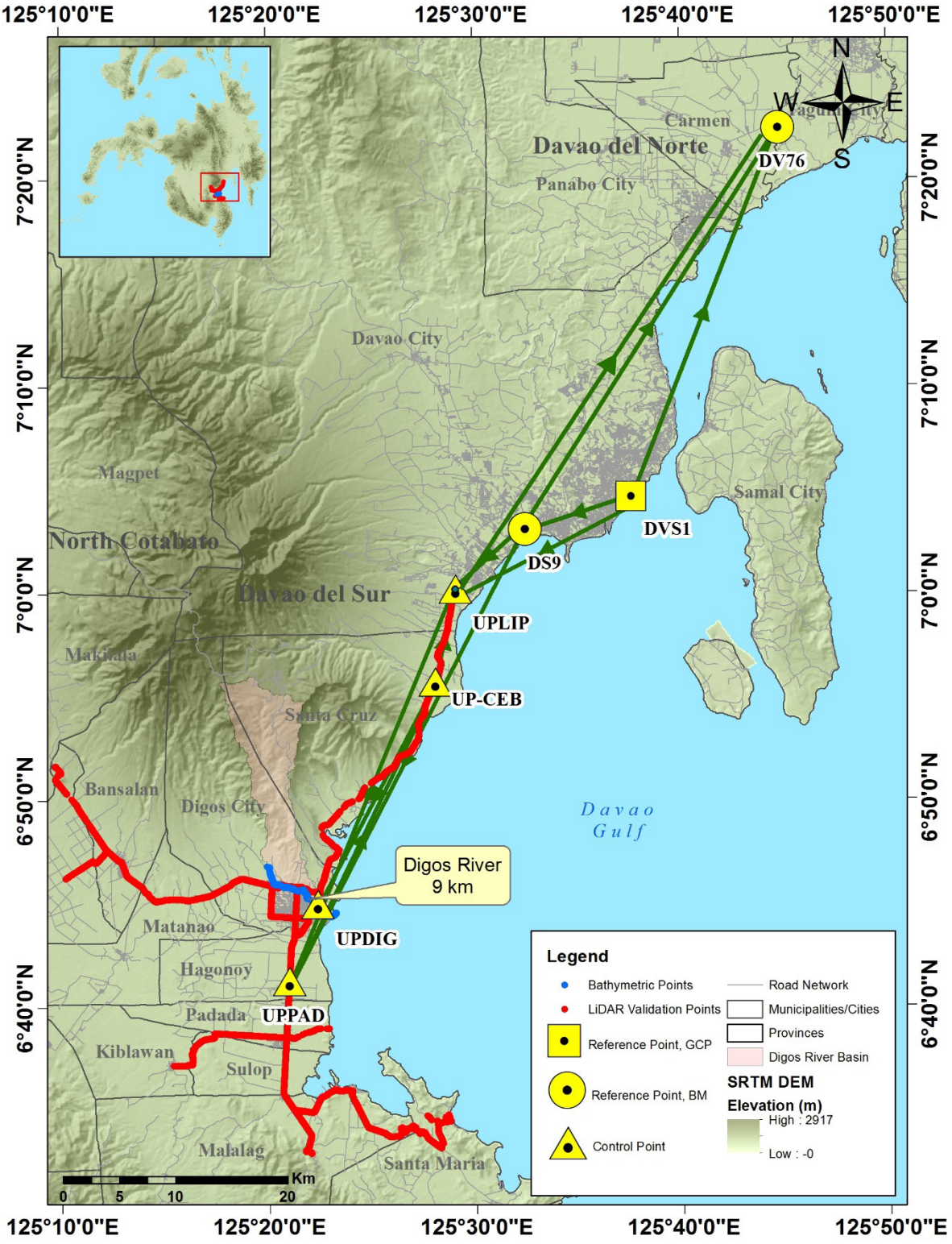


Figure 26. Digos River survey extent

4.2 Control Survey

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

Five (5) control points were established along approach of bridges namely: UP-CEB at Cebulan Bridge in Brgy. Darong, Municipality of Sta. Cruz Davao Del Sur; UP-DIG in Digos Bridge in Brgy. Aplaya, Digos City,

Davao Del Sur; UP-LIP2 at Lipadas Bridge approach in Brgy. Lizada, Davao City, Daao Del Sur; and UP-PAD at Padada Bridge, in Brgy. Guihing, Muncipality of Hagonoy, Davao Del Sur. A NAMRIA established control point namely DS-9, located in Brgy. Talomo, Davao City, was also occupied to use as marker during the survey.

The summary of reference and control points and its location is summarized in Table 21, and the GNSS network established is illustrated in Figure 27.

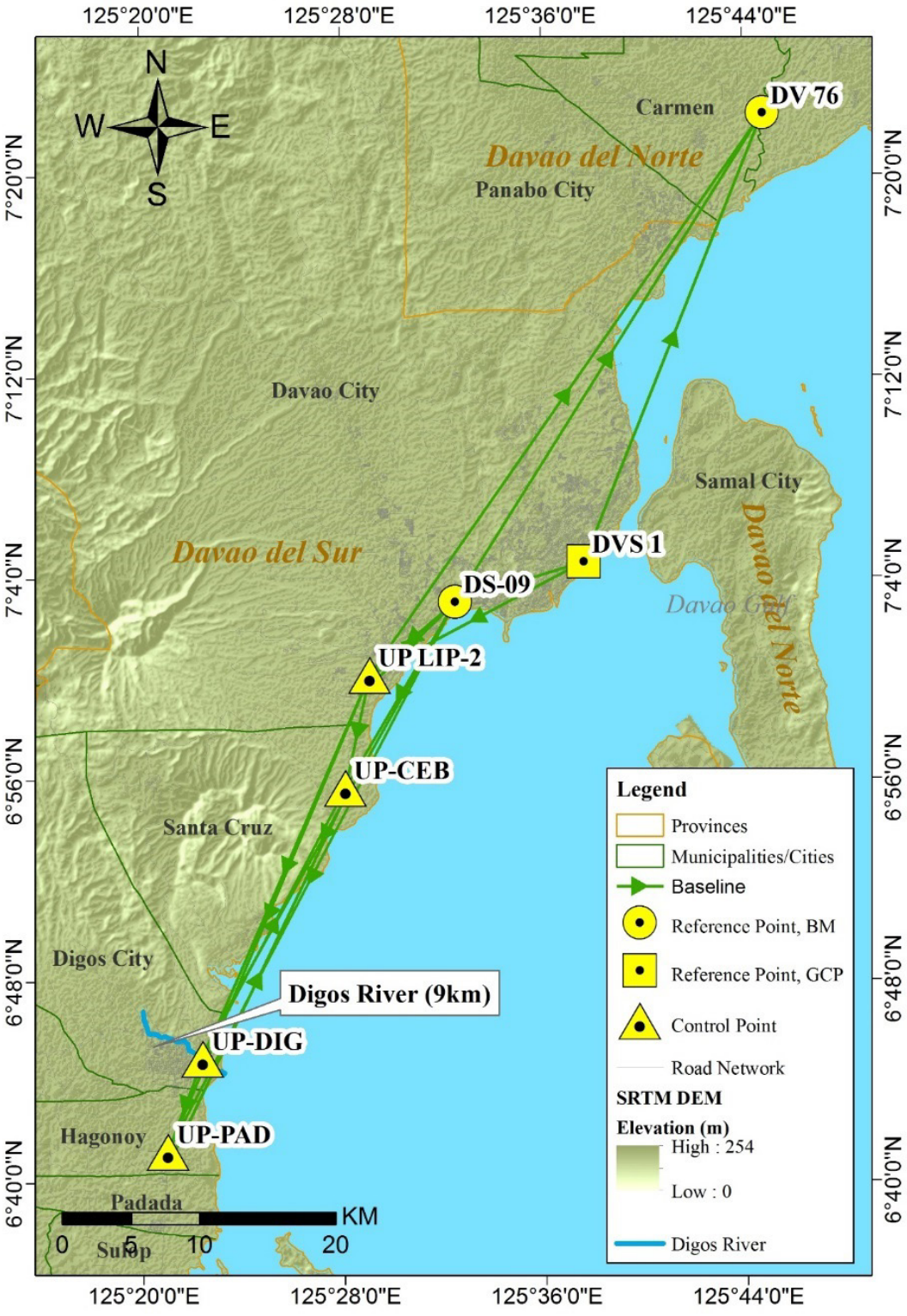


Figure 27. Overall GNSS Survey loop of Digos River Basin

Table 21. List of Reference and Control Points used in Digos River Survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	BM Ortho (m)	Date Established
DVS-1	1st order GCP	7°04'38.36201"	125°37'36.77094"	68.5	-	2013
DV-76	1st order BM	-	-	76.155	8.359	2007
DS-9	Used as Marker	-	-	-	-	2007
UP-CEB	UP Established	-	-	-	-	7-5-2015
UP-DIG	UP Established	-	-	-	-	7-5-2015
UP-LIP2	UP Established	-	-	-	-	7-4-2015
UP-PAD	UP Established	-	-	-	-	7-5-2015

The GNSS set up for control points used are shown in Figure 28 to Figure 34, respectively.

Figure 28. GNSS base receiver setup, Trimble® SPS 852 at DVS-1 at the east side of Pier, in Brgy. Leon Garcia Sr., Davao City, Davao Del Sur

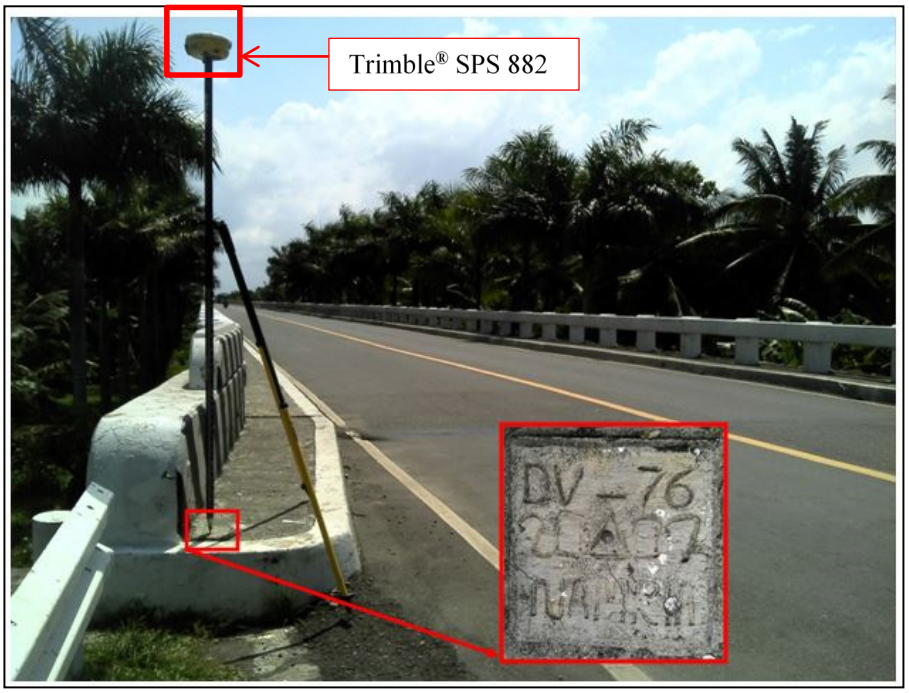


Figure 29. GNSS base receiver setup, Trimble® SPS 882 at DV-76 at the Gov. Miranda Bridge Approach, Brgy. Guadalupe, Municipality of Carmen, Davao Del Norte

Figure 30. GNSS base receiver setup, Trimble® SPS 882 at DS-09 located at stair of Nograles Park along Mac Arthur Highway, in Brgy. Talomo, Davao City, Davao Del Sur

Figure 31. GNSS base receiver setup, Trimble® SPS 852 at UP-CEB on the right approach of Cebulan Bridge in Brgy Darong, Municipality of Santa Cruz, Davao Del Sur

Figure 32. GNSS base receiver setup, Trimble® SPS 882 at UP-DIG, right approach of Digos Bridge in Brgy. Aplaya, Digos City, Davao Del Sur

Figure 33. GNSS base receiver setup, Trimble® SPS 852 at UP-LIP2, on the right approach of Lipadas Bridge along National Highway in Brgy. Lizada, Toril District, Davao Del Sur

Figure 34. GNSS base receiver setup, Trimble® SPS 882 at UP-PAD, Padada Bridge, Brgy. Guihing, Municipality of Hagonoy, Davao del Sur

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Digos River Basin is summarized in Table 22, generated by TBC software.

Table 22. Baseline Processing Report for Digos River Basin Static Survey

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

As shown in Table 22 a total of 18 baselines were processed and all of them passed the required accuracy set by the project.

4.4 Network Adjustment

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

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

where:

xe is the Easting Error,
ye is the Northing Error, and
ze is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 23 to Table 25 for the complete details.

The seven (7) control points, DVS-1, DV-76, DS-9, UP-CEB, UP-DIG, UP-LIP2 and UP-PAD were occupied and observed simultaneously to form GNSS LOOP. Coordinates of DVS-1 and elevation value of DV-76 were held fixed during the processing of the control points as presented in Table 23. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 23. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
DVS-1	Global	Fixed	Fixed		
DV-76	Grid				Fixed
FIXED = 0.000001(METER)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 24. The fixed control point DV-76 and DVS-1, has no values for standard elevation and coordinates error, respectively.

Table 24. Adjusted Grid Coordinates

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

The networks are fixed at reference points DVS-1 and DV-76. With the mentioned equation, and for the vertical, the computations for the horizontal and vertical accuracy are as follows:

a. DVS-1
horizontal accuracy = Fixed
vertical accuracy = 6.4cm < 10 cm

b .DV-76
horizontal accuracy = $\sqrt{((0.8)^2 + (0.8)^2}$
$= \sqrt{(0.64 + 0.64)}$
= 1.13 cm < 20 cm
vertical accuracy = Fixed

c. DS-09
horizontal accuracy = √((0.9)² + (0.7)²
= √(0.81 + 0.49)
= 1.14 cm < 20 cm
vertical accuracy = 7.9 cm < 10 cm

d. UP-CEB
horizontal accuracy = √((1.2)² + (1.1)²
= √(1.44 + 1.21)
= 2.69 cm < 20 cm
vertical accuracy = 1.63 cm < 10 cm

e. UP-DIG
horizontal accuracy = √((1.1)² + (0.9)²
= √(1.21 + 0.81)
= 1.42 cm < 20 cm
vertical accuracy = 9.0 cm < 10 cm

f. UP-LIP2
horizontal accuracy = √((0.8)² + (0.7)²
= √(0.64+ 0.49
= 1.06 cm < 20 cm
vertical accuracy = 7.2 cm< 10 cm

g. UP-PAD
horizontal accuracy = √((1.1)² + (1.0)²
= √(1.21 + 1.0)
= 1.49 cm < 20 cm
vertical accuracy = 8.9 cm < 10 cm

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

Table 25. Adjusted geodetic coordinates

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

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 26.

Table 26. Reference and control points and its location (Source: NAMRIA, UP-TCAGP)

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

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

Cross-section and as-built surveys were conducted on July 6, 2015 in the downstream side of Digos Bridge in Brgy. Aplaya, Digos City Davao Del Sur using a GNSS receiver, Trimble® SPS 882, in PPK survey technique as shown in Figure 35. Bridge as-built features determination was also performed to get the distance of piers and abutments from the bridge approach. The bridge deck was measured using GNSS receiver Trimble® SPS 882 to get the high chord and meter tapes to get its low chord elevation.

Figure 35. Cross-section survey at the downstream side of Digos Bridge in Brgy. Aplaya, Digos City, Davao Del Sur

The cross-sectional line length in Digos Bridge is about 85.63 meters with 43 cross-sectional points using UP-DIG as the GNSS base station. The summary of gathered cross-section and as-built data for Digos Bridge are illustrated in Figure 36 to Figure 38, respectively.

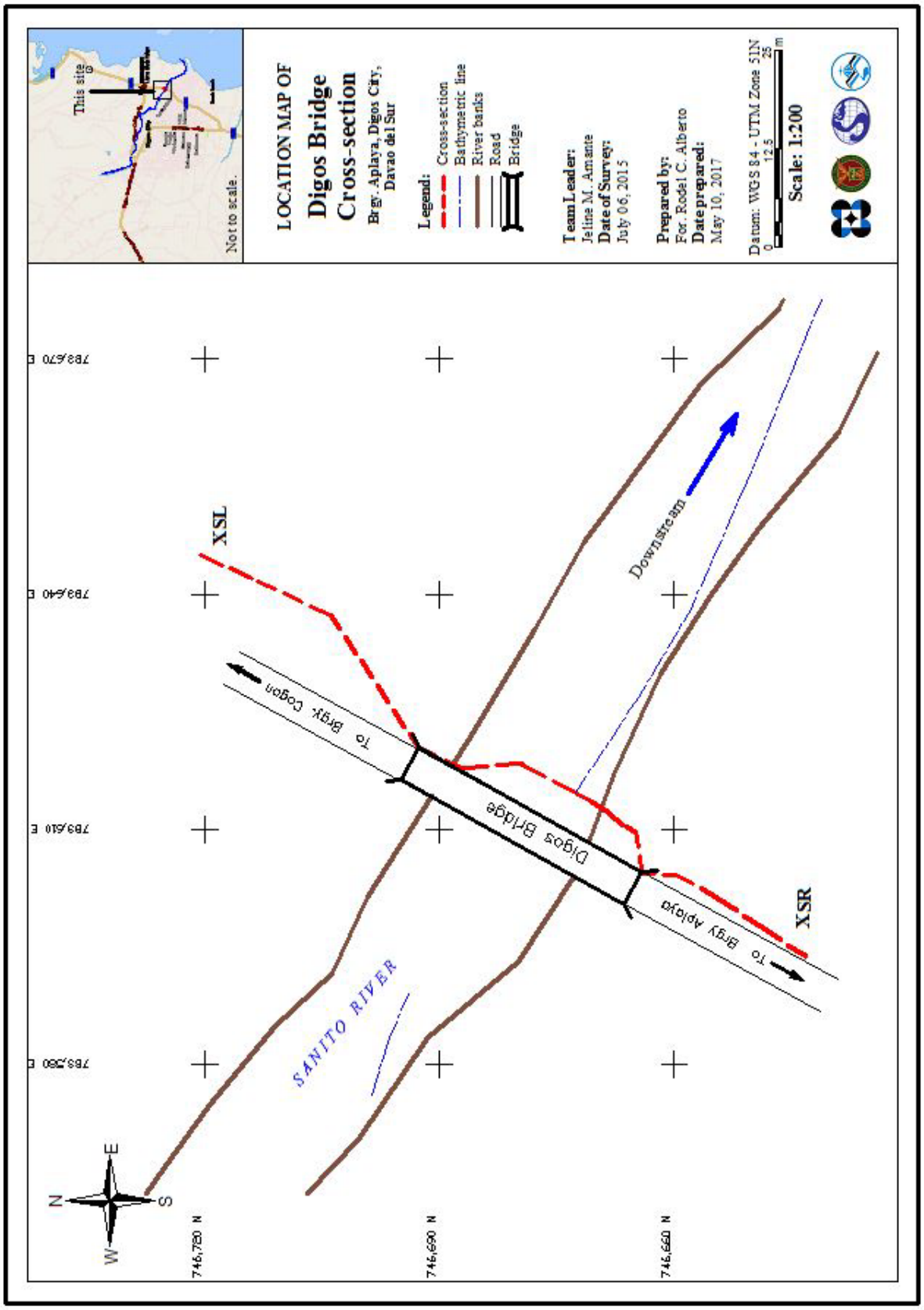


Figure 36. Digos bridge cross-section location map

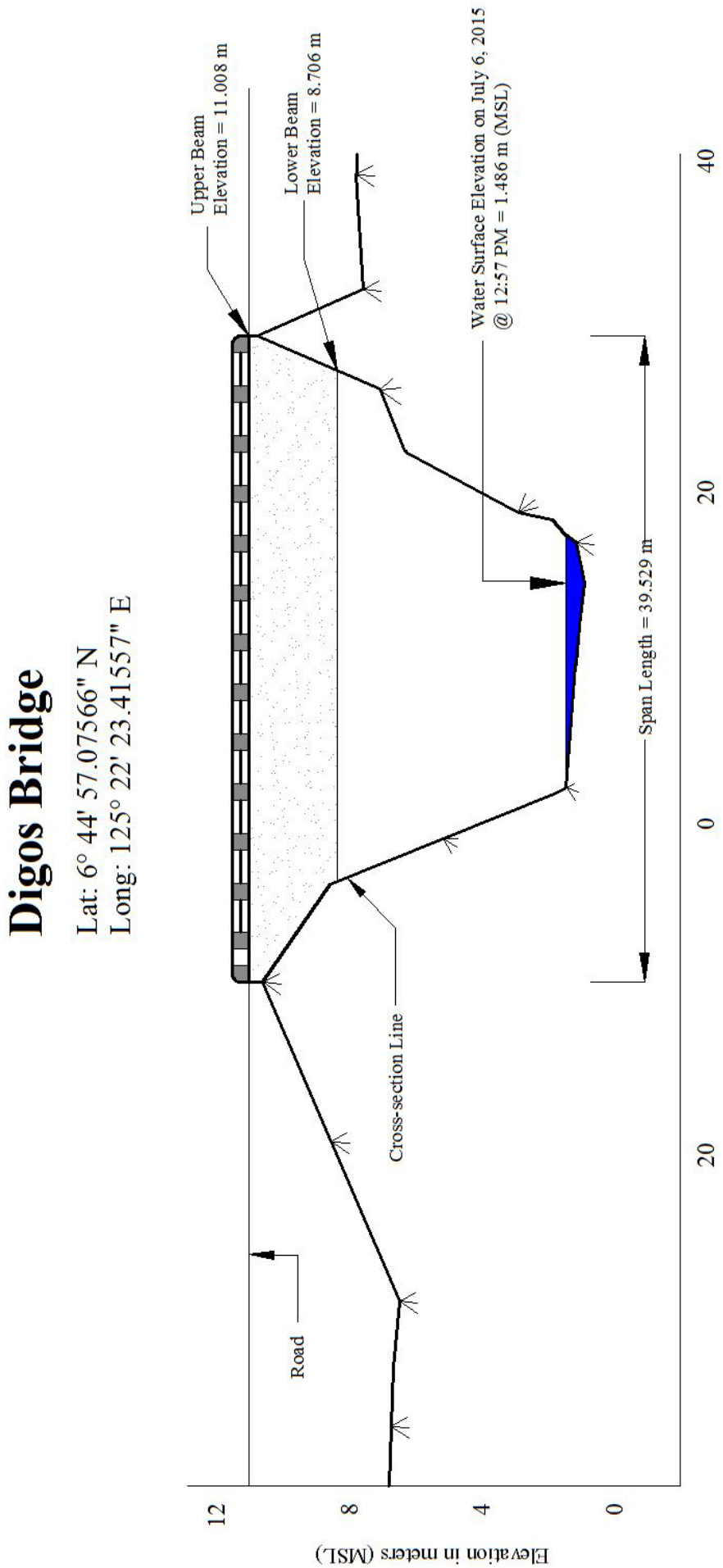


Figure 37. Digos Bridge cross-section diagram

Bridge Data Form

Bridge Name: DIGOS BRIDGE Date: July 06, 2015

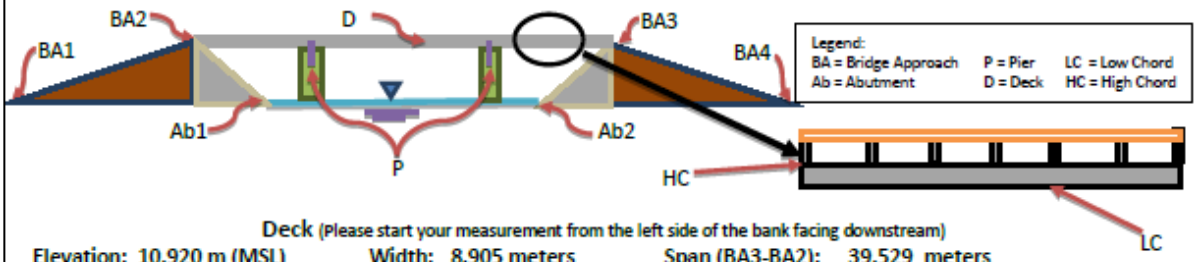
River Name: DIGOS RIVER Time: 4:03 pm

Location (Brgy, City, Region): Brgy. Aplaya, Digos, Davao del Sur

Survey Team: DVBC/DVC Davao del Sur Survey Team

Flow condition: low normal high Weather Condition: fair rainy

Latitude: 6°44'57.07566"N Longitude: 125°22'23.41557" E



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

Elevation: 10.920 m (MSL) Width: 8.905 meters Span (BA3-BA2): 39.529 meters

	Station	High Chord Elevation	Low Chord Elevation
1	-	11.008 m	8.706 m
2			
3			
4			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	35.0282	BA3	39.481	35.368
BA2	7.275	35.3882	BA4	63.184	34.78

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

	Station (Distance from BA1)	Elevation
Ab1	-	-
Ab2	-	-

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

Shape: N/A Number of Piers: 0 Height of column footing: _____

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	No pier	-	-
Pier 2	No pier	-	-
Pier 3	-	-	-
Pier 4	-	-	-

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

Figure 38. Digos Bridge Data Form

Water surface elevation in MSL of Digos River was determined using Trimble® SPS 882 in PPK mode survey on July 6, 2015 at 12:57 PM. This was translated onto marking the bridge's pier using a digital level. The resulting water surface elevation data is 1.486 m above MSL. The markings on the bridge pier shall serve as a reference for flow data gathering and depth gauge deployment of UP-Mindanao PHIL-LIDAR 1 as shown in Figure 39.

Figure 39. MSL water level markings in Digos Bridge's Pier

4.6 Validation Points Acquisition Survey

Validation Points Acquisition Survey was conducted on July 8 and 11, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached in front of the vehicle as shown in Figure 40. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height of 1.426 m was measured from the ground up to the bottom of the notch of the GNSS SPS 882 Rover receiver on the first day. The second validation survey antenna height is measured to be 1.382m. The surveys were conducted using PPK technique on a continuous topography mode using UP-PAD as base station.

The first day of ground validation survey covered the major roads of Santa Cruz, Digos City, Hagonoy, Padada, Sulop, Kiblawan, and Matanao. The second day of the ground validation covered the major roads of Bansalan and Magsaysay. The survey acquired 12,851 ground validation points with an approximate length of 84.5 km as presented in Figure 41. The gaps in the validation line were due to some difficulties in receiving satellite signals because of the presence of obstruction such as dense canopy cover of trees along the roads.

Figure 40. Validation points acquisition survey setup

Figure 41. LiDAR Ground validation survey along Digos River Basin

4.7 River Bathymetric Survey

Manual bathymetric survey was conducted on July 6 to July 10, 2015 using Trimble® SPS 882 in GNSS PPK survey technique as shown in Figure 42. The survey started in the upstream part of the river in Brgy. Ruparan, Digos City with coordinates 6°46'46.28705" 125°20'01.70541", traversed down the river by foot and ended at the mouth part of the river in Brgy. Aplaya and Brgy. Cogon, also in Digos City, with coordinates 6°44'32.68265" 125°23'14.79631". The control point UP-DIG was used as the GNSS base station all throughout the survey.

Figure 42. Manual bathymetric survey in Digos River

The bathymetry survey traverses the Barangays of Tres De Mayo and Brgy. Zone 2 and the Bridges of Canos and Digos, then ending at Brgy. Aplaya with an estimated length of 9 km with a total of 1,359 bathymetric points gathered. The gaps in the bathymetric line as shown in Figure 43 were due to some difficulties in acquiring satellite due to the presence of obstruction such as dense canopy cover of trees along the path traversed.

Figure 43. Bathymetric points gathered from Digos River

A CAD drawing illustrating the Digos Riverbed profile was also produced as shown in Figure 44 where the highest elevation record is observed in Brgy. Tres De Mayo and the lowest in Brgy. Aplaya. An elevation drop of 37 meters was observed within the total distance surveyed.

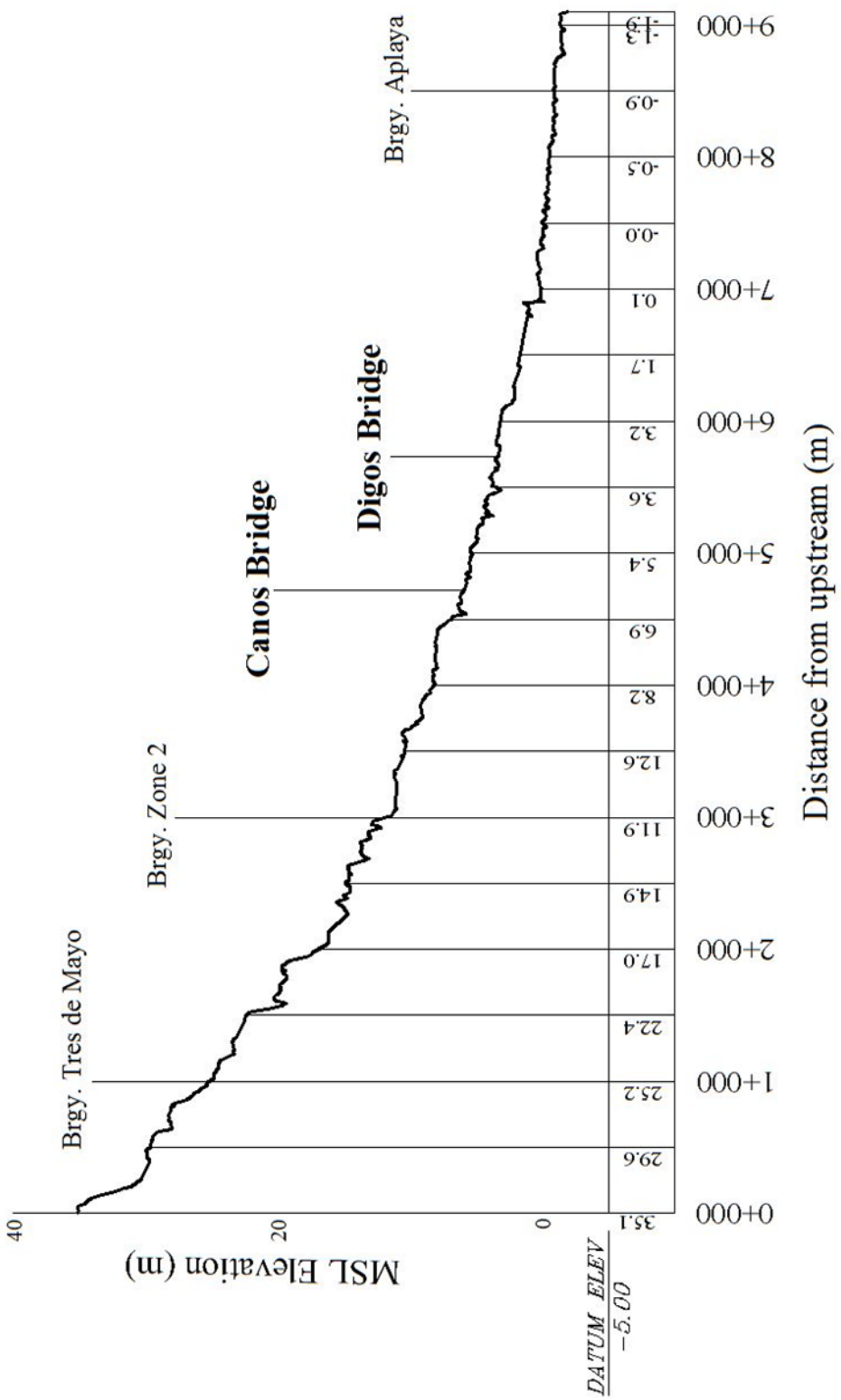


Figure 44. Digos riverbed centerline profile

CHAPTER 5. FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

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

5.1.1 Hydrometry and Rating Curves

5.1.2 Precipitation

Precipitation data was taken from the rain gauge installed by the University of the Philippines Mindanao Phil-LiDAR 1 at Barangay Goma, Digos City, Davao del Sur. The location of the rain gauge is seen in Figure 45.

Total rain from the rain gauge is 14 mm. It peaked to 5.2 mm on 14 September 2015, 12:45. The lag time between the peak rainfall and discharge is 10 hours and 15 minutes.

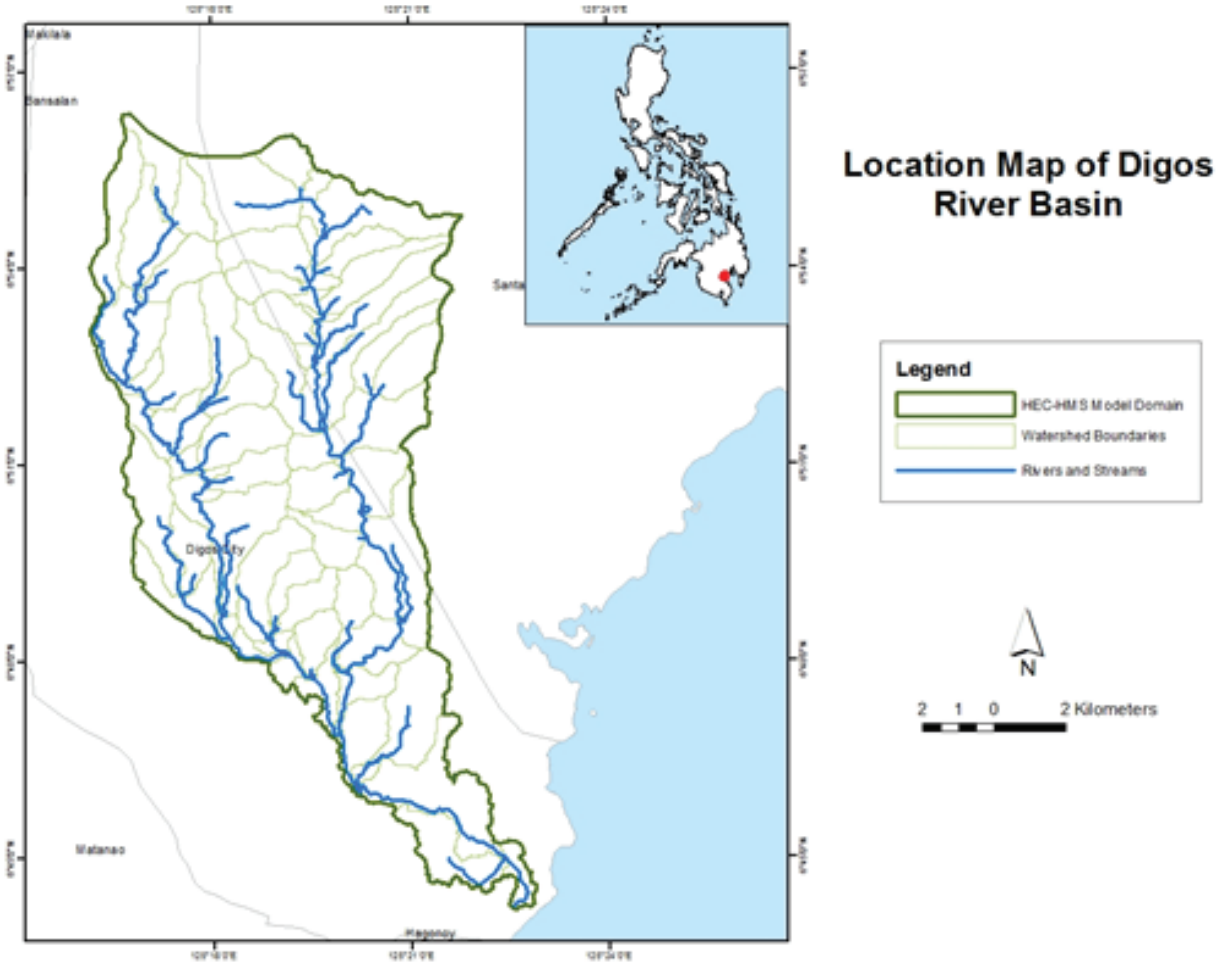


Figure 45. The location map of Digos HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Digos Bridge 2, Aplaya, Digos City (6°44'57.14"N, 125°22'23.53"E). It gives the relationship between the observed water levels at Digos Bridge and outflow of the watershed at this location.

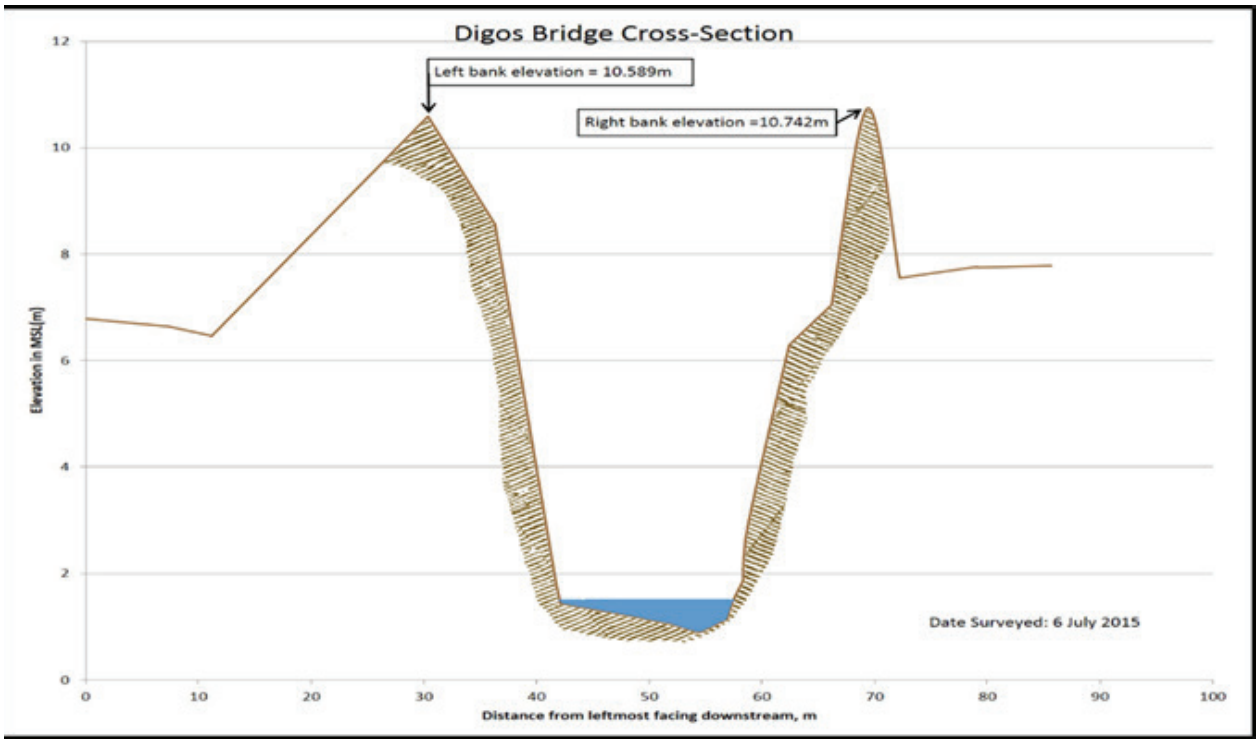


Figure 46. Cross-Section Plot of Digos Bridge

For Digos Bridge, the rating curve is expressed as Q = 0.0077e3.2618h as shown in Figure 47.

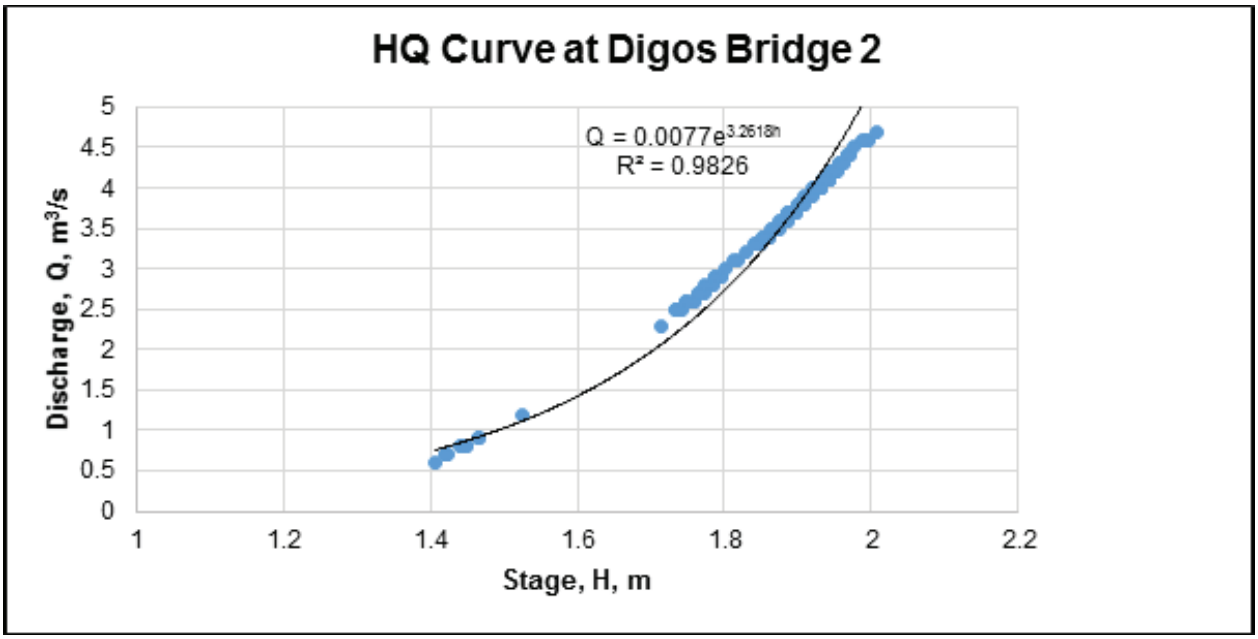


Figure 47. Rating Curve at Digos Bridge 2, Aplaya, Digos City

This rating curve equation was used to compute the river outflow at Digos Bridge 2 for the calibration of the HEC-HMS model shown in Figure 48 Peak discharge is 4.7 cms at 23:00, September 14, 2015.

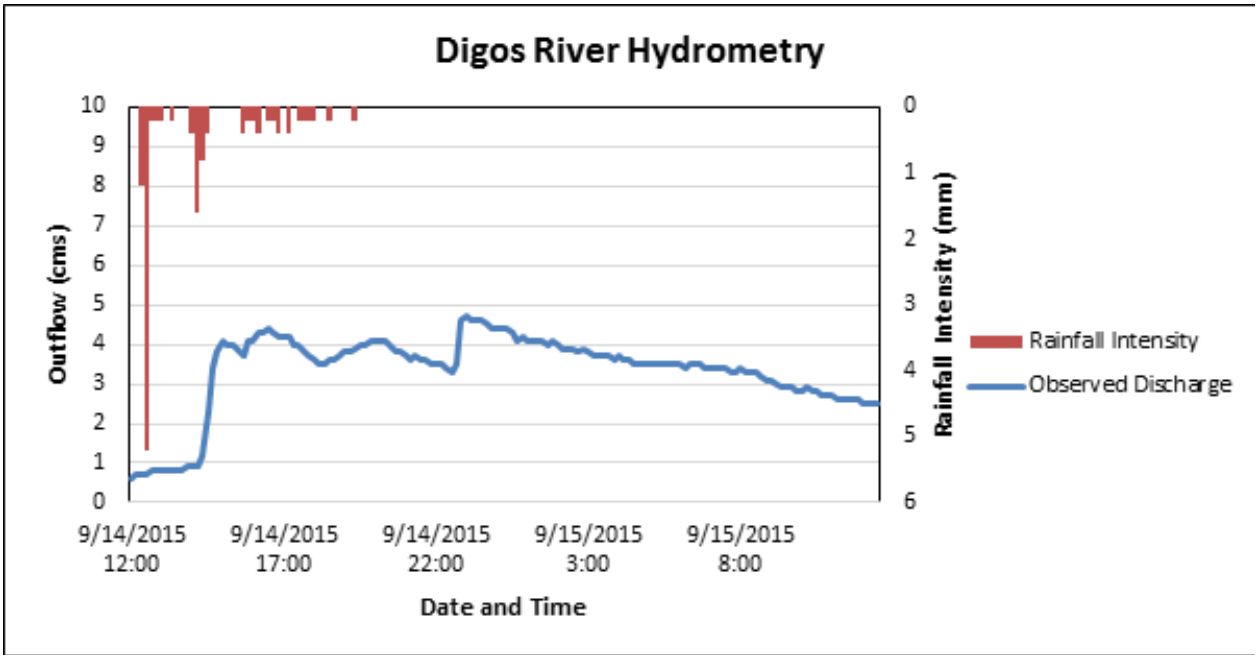


Figure 48. Rainfall and outflow data at Digos used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Davao Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station chosen based on its proximity to the Digos watershed. The extreme values for this watershed were computed based on a 26-year record.

Table 27. RIDF values for Davao Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	2	19.5	30	38.2	53.2	65.2	71.6	80.3	85.8
5	5	25.1	39.3	51	73.2	88.8	96.4	108.7	114.9
10	10	28.8	45.4	59.4	86.5	104.5	112.8	127.5	134.1
15	15	30.9	48.9	64.2	94	113.3	122.1	138.1	145
20	20	32.4	51.3	67.6	99.3	119.5	128.6	145.5	152.6
25	25	33.5	53.2	70.1	103.3	124.2	133.6	151.2	158.5
50	50	37	59	78.1	115.8	138.9	149	168.8	176.5
100	100	40.5	64.7	85.9	128.1	153.5	164.2	186.3	194.4

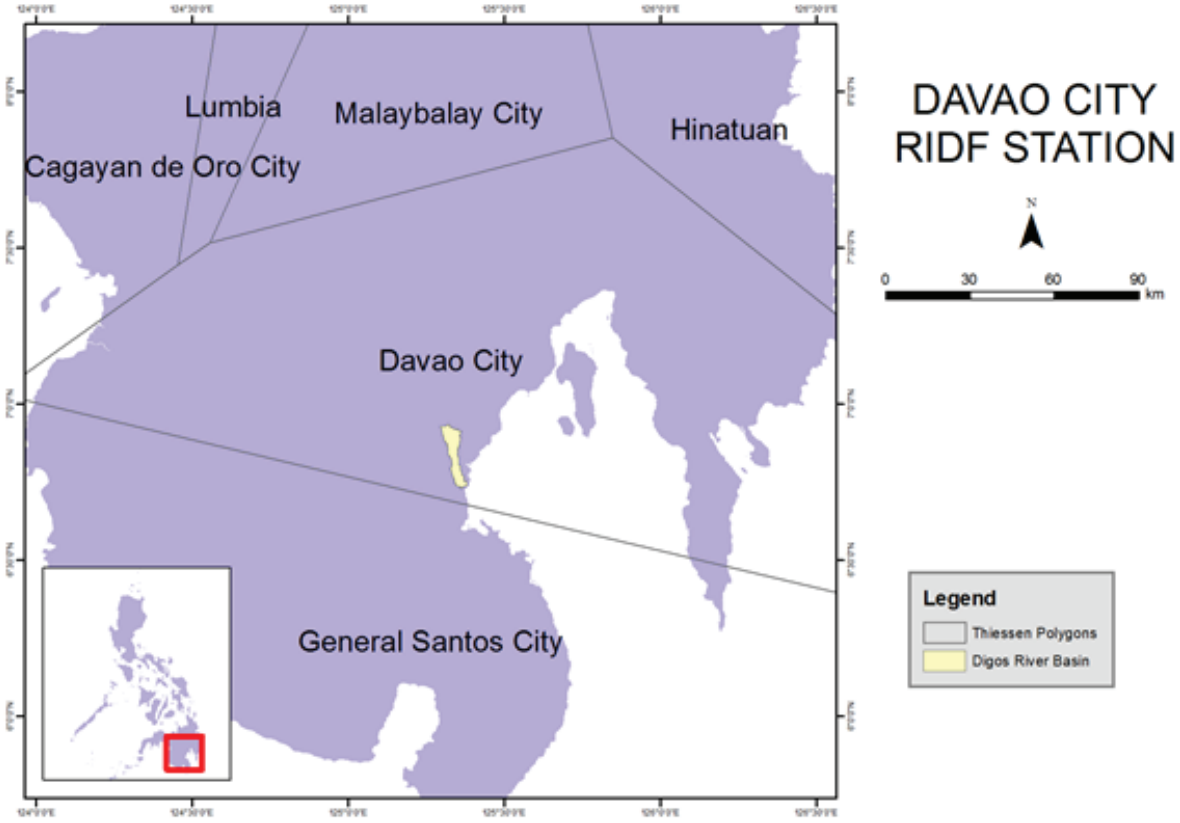


Figure 49. Davao RIDF location relative to Digos River Basin

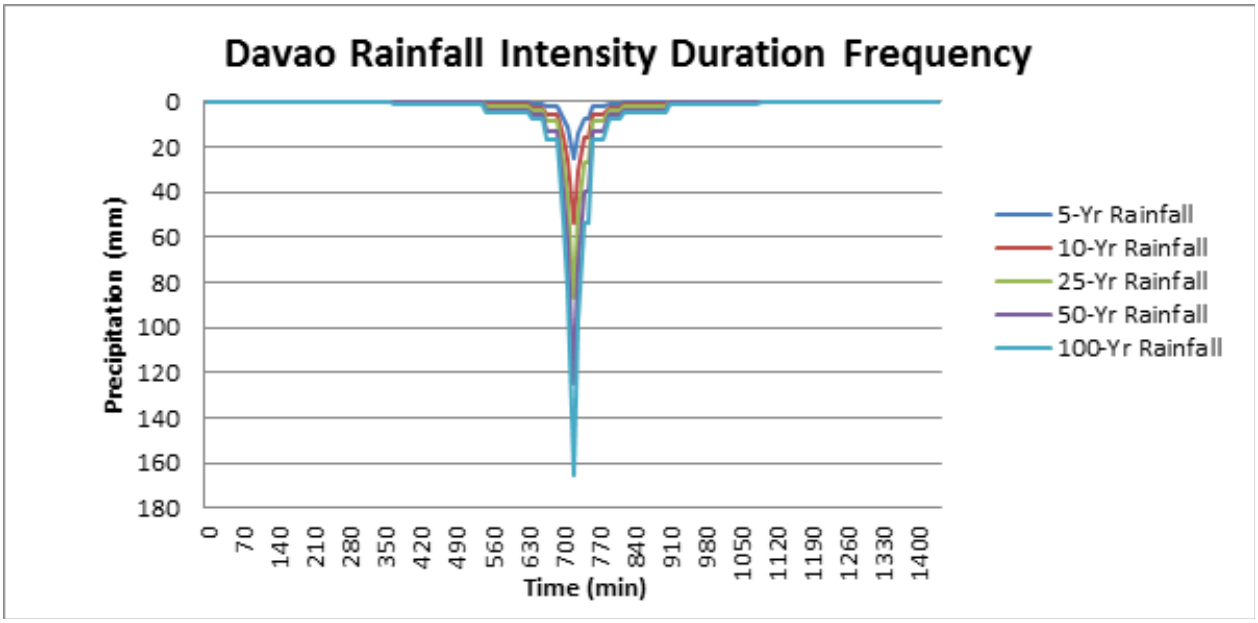


Figure 50. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken before 2004 by the Bureau of Soils and Water Management (BSWM), under the Department of Agriculture (DA). The land cover dataset file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Digos River Basin are shown in Figures 51 and 52, respectively.

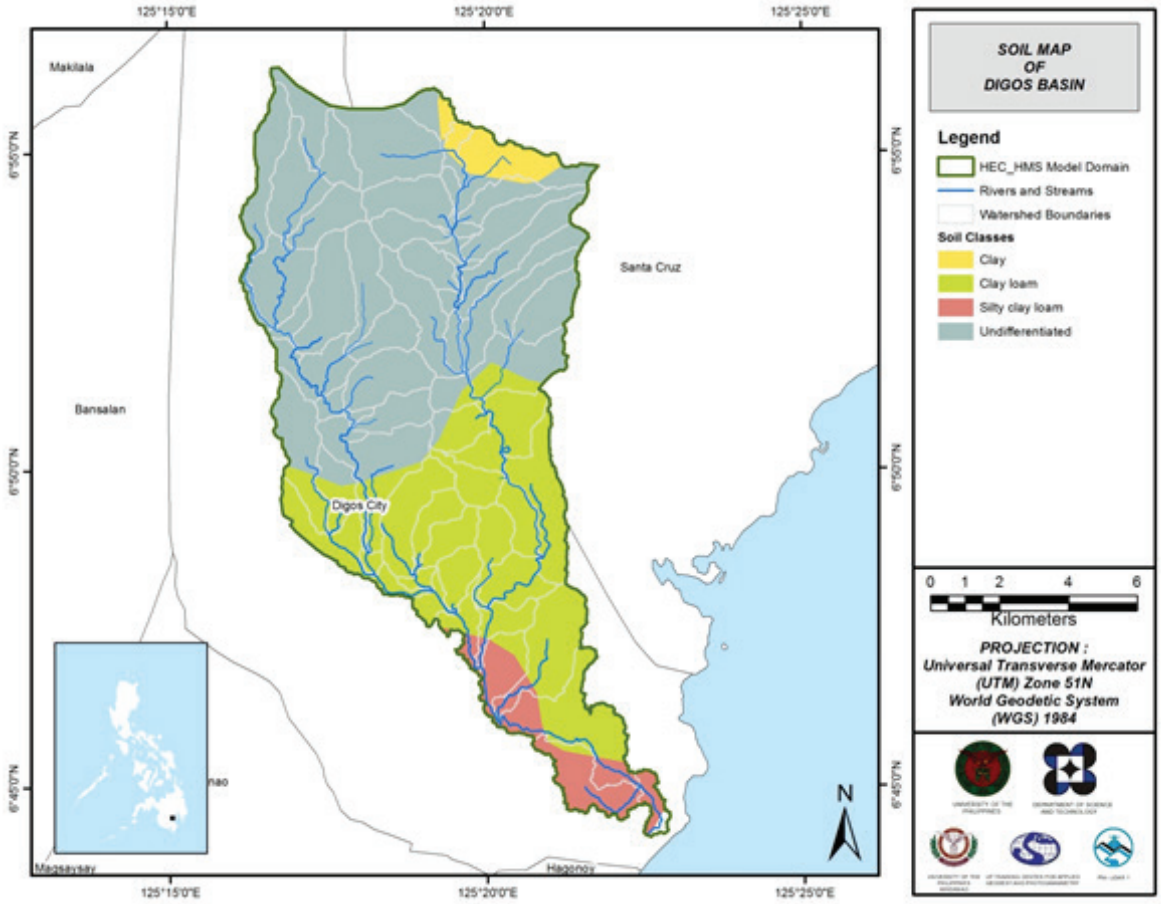


Figure 51. Soil Map of Digos River Basin

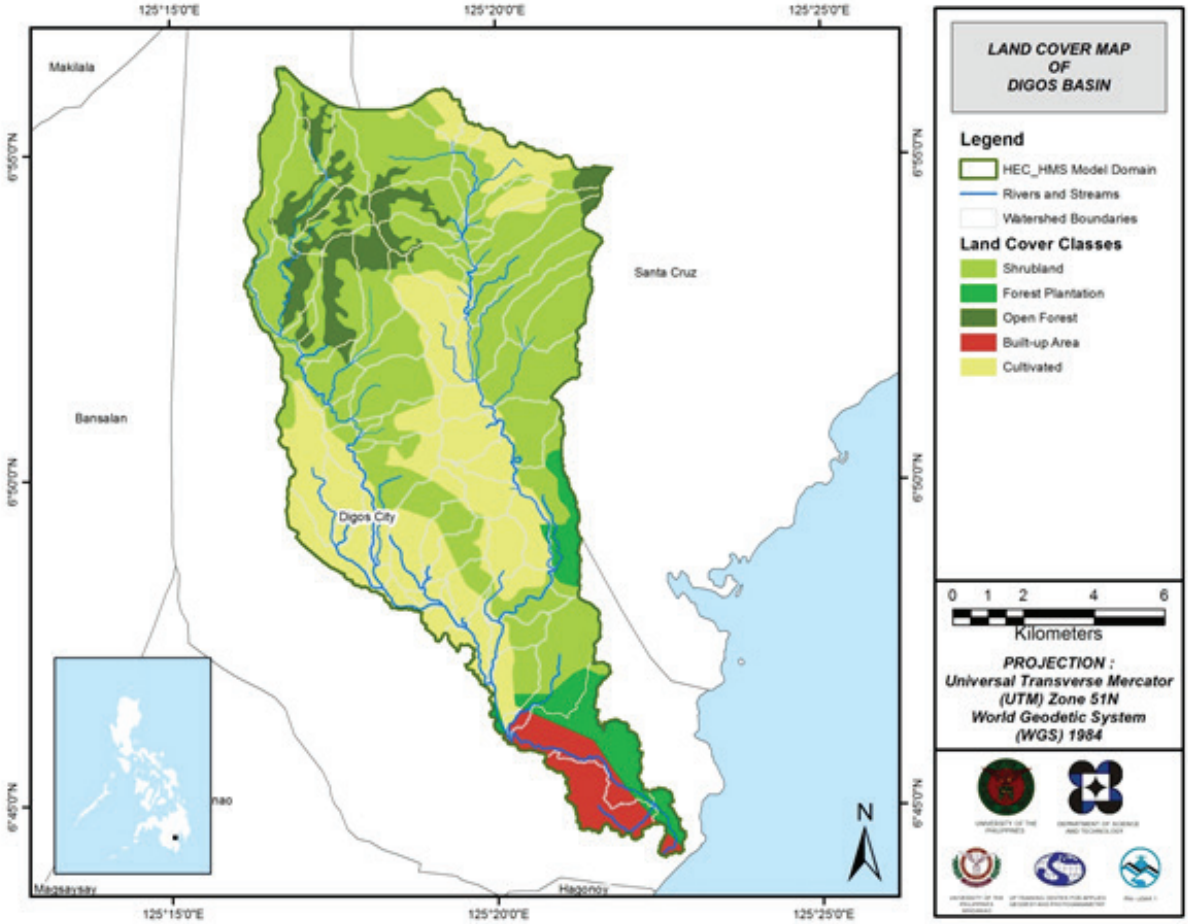


Figure 52. Land Cover Map of Digos River Basin (Source: NAMRIA)

For Digos, four soil classes were identified. These are clay, clay loam, silty clay loam and undifferentiated land. Moreover, five land cover classes were identified. These are shrublands, forest plantations, open forest, built-up areas, and cultivated areas.

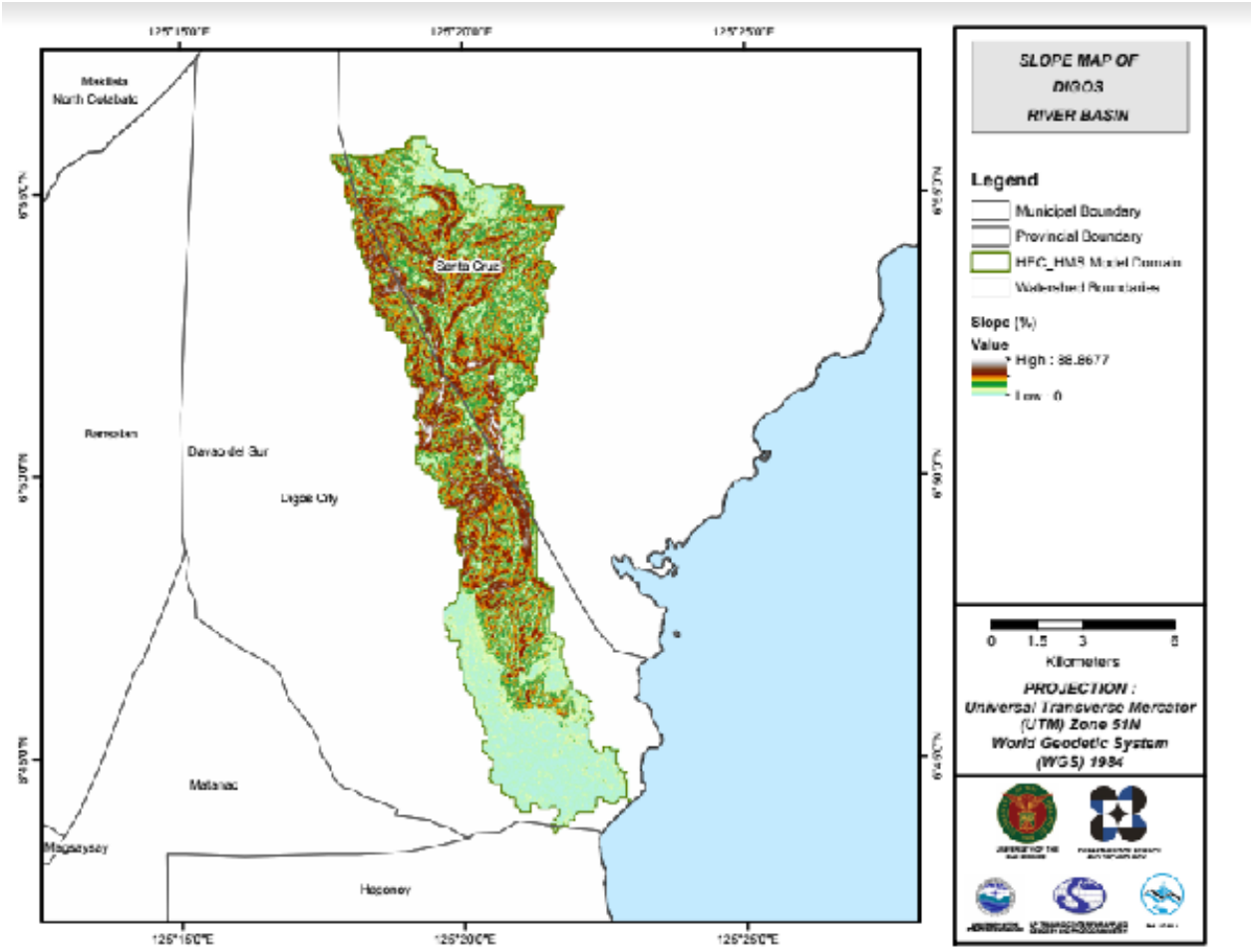


Figure 53. Slope map of the Digos River Basin

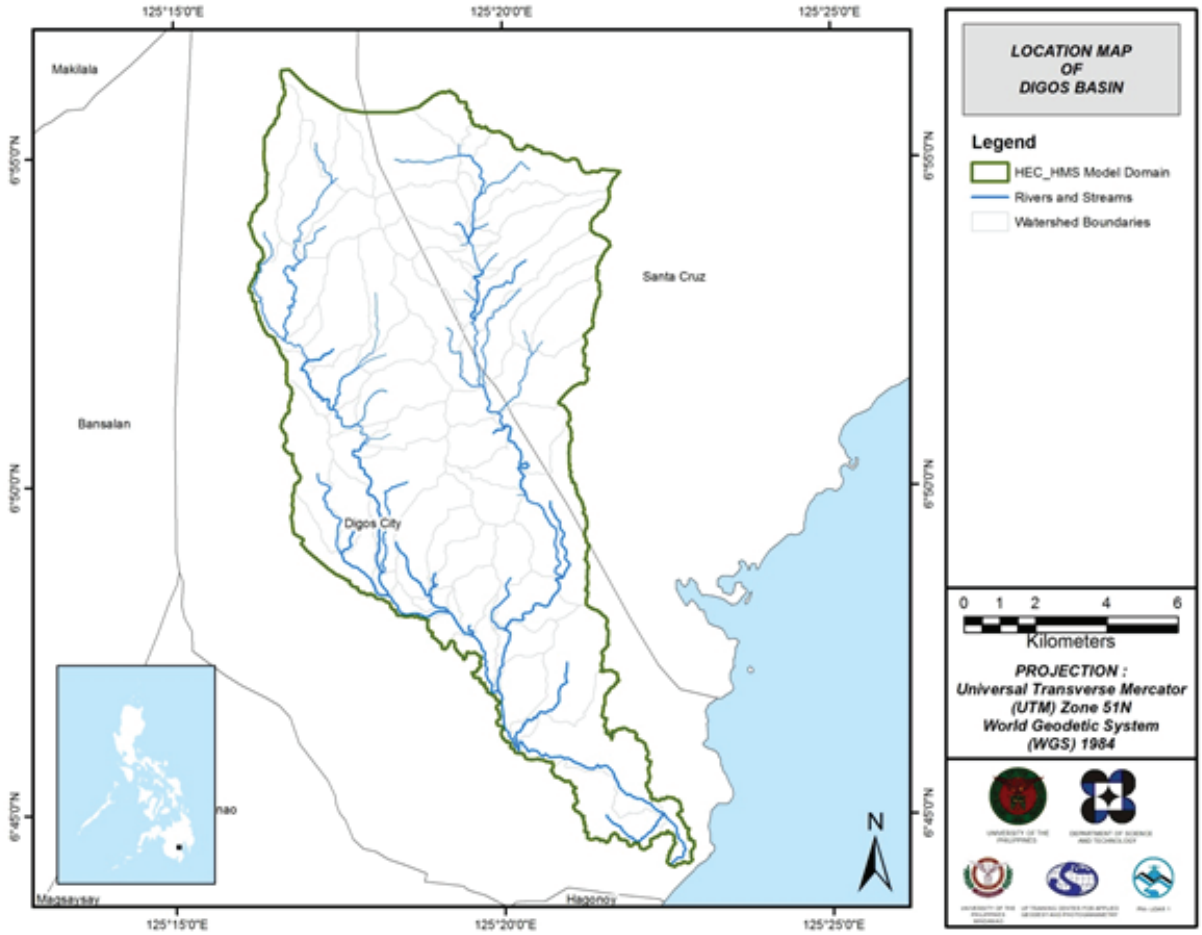


Figure 54. Stream Delineation Map of Digos River Basin

Using the SAR-based DEM, the Digos basin was delineated and further subdivided into subbasins. The model consists of 69 sub basins, 34 reaches, and 34 junctions as shown in Figure 56. The main outlet is at Digos Bridge.

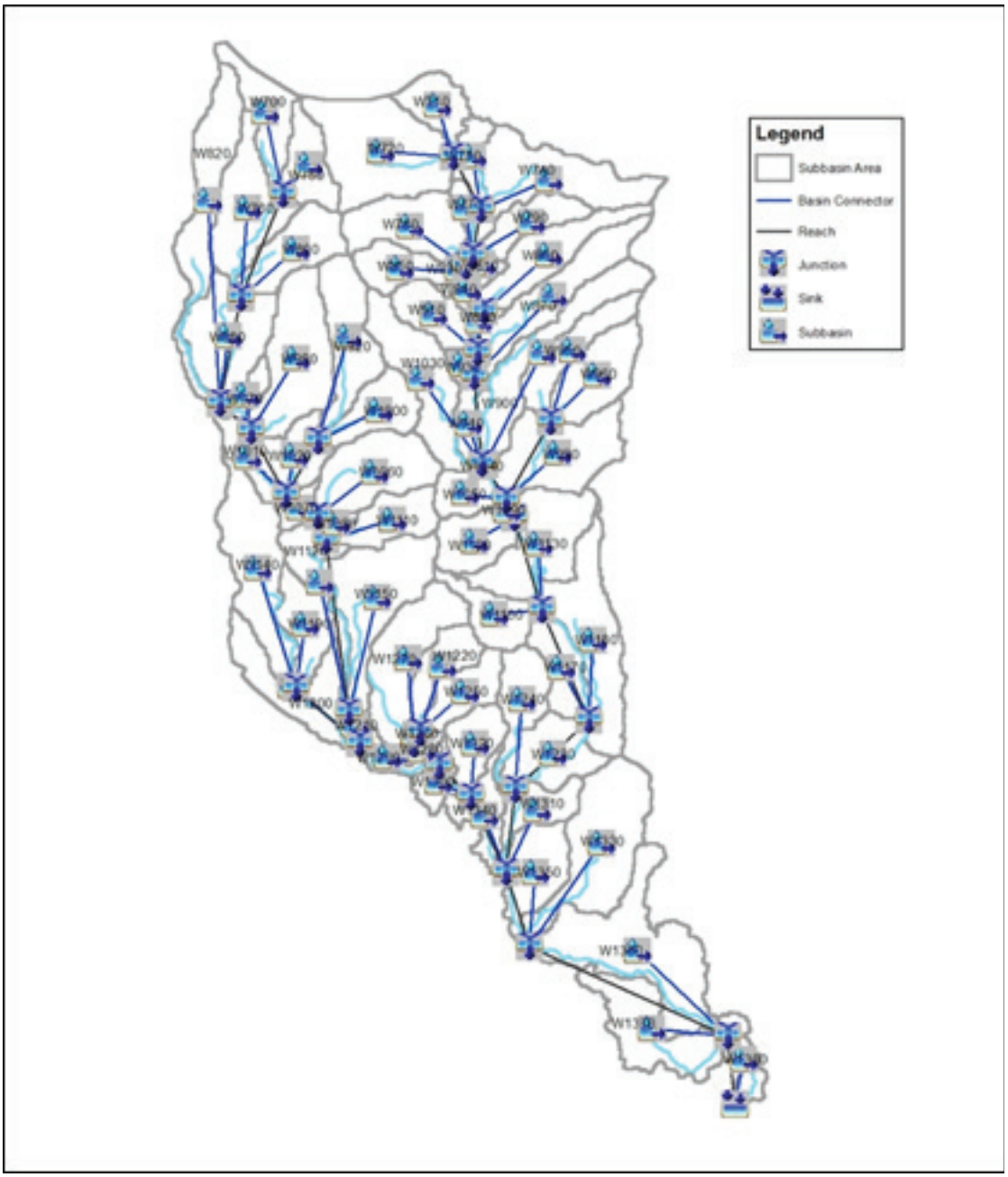


Figure 55. The Digos river basin model generated using HEC-HMS

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.

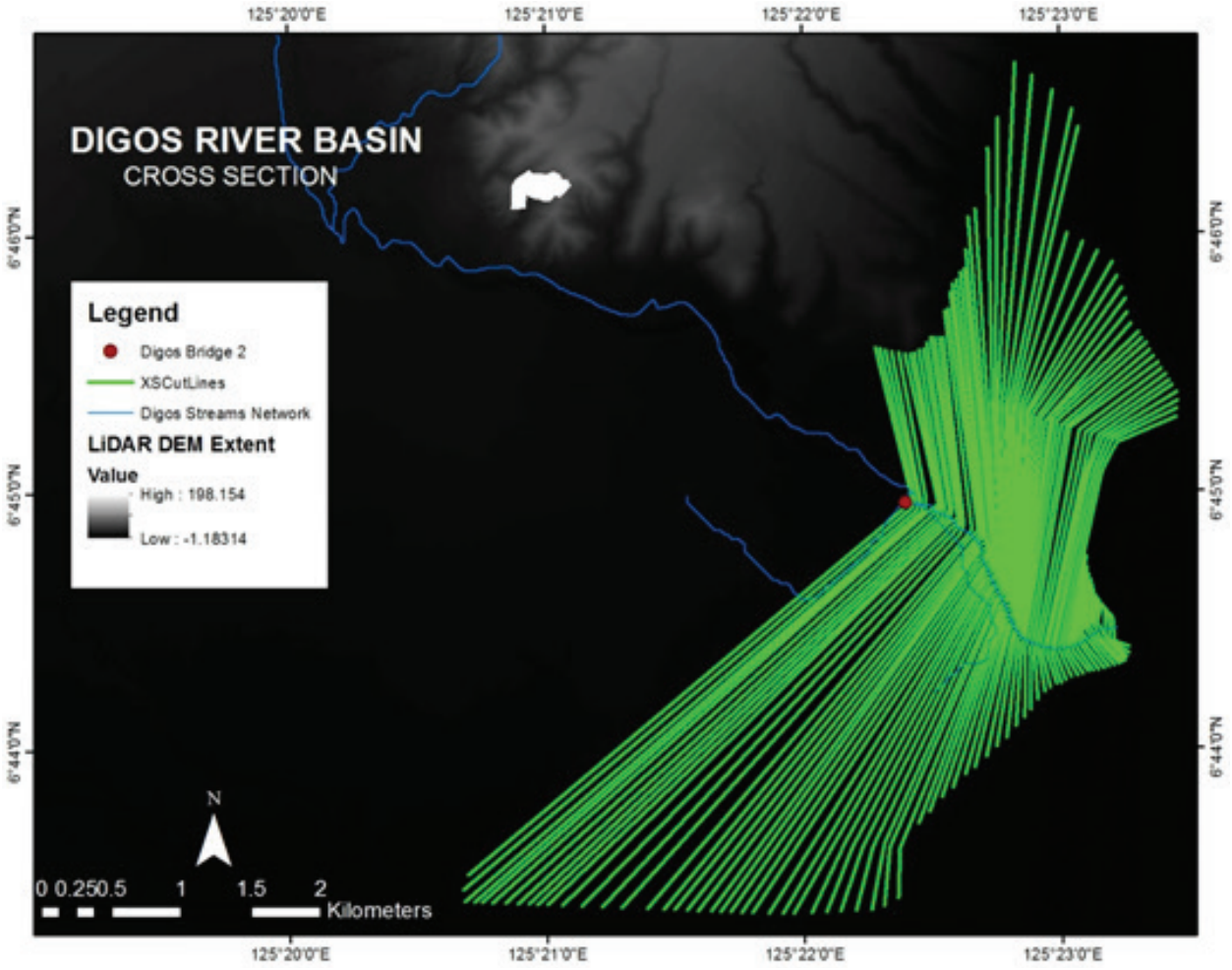


Figure 56. River cross-section of Digos River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

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

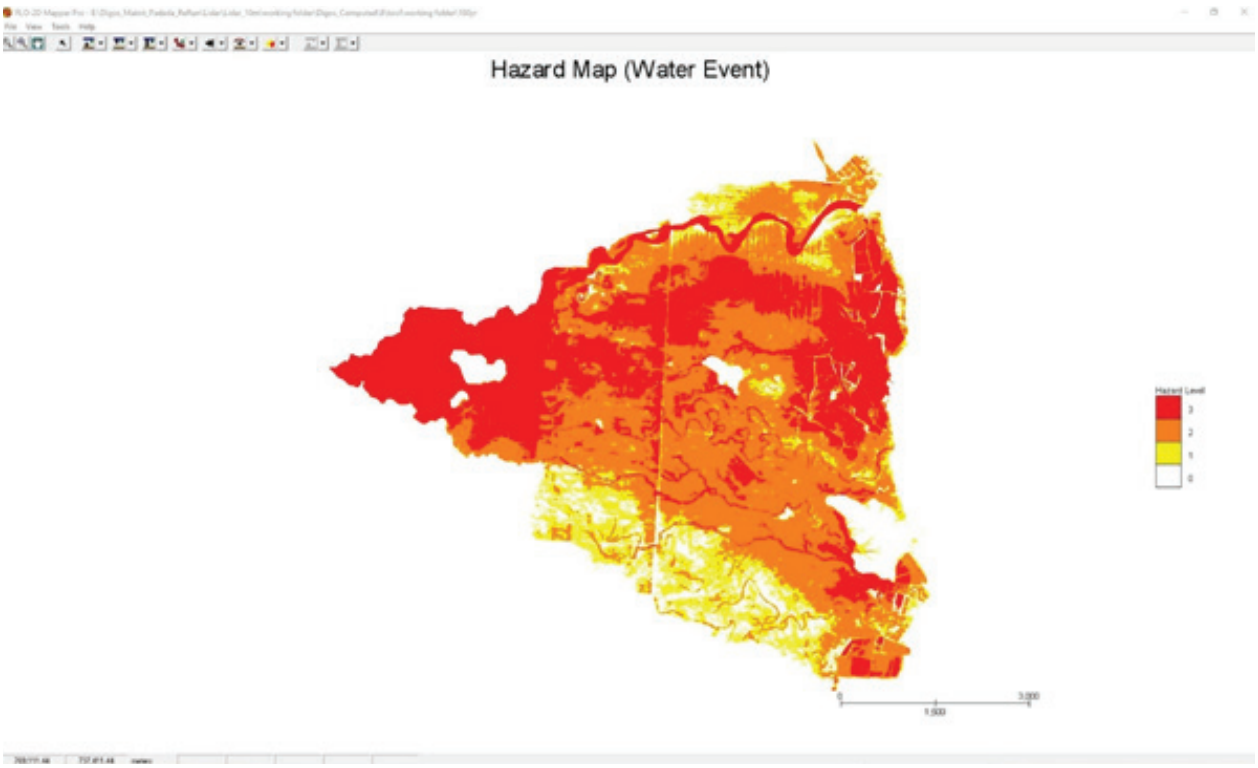


Figure 58. Generated 100-year rain return hazard map from FLO-2D Mapper

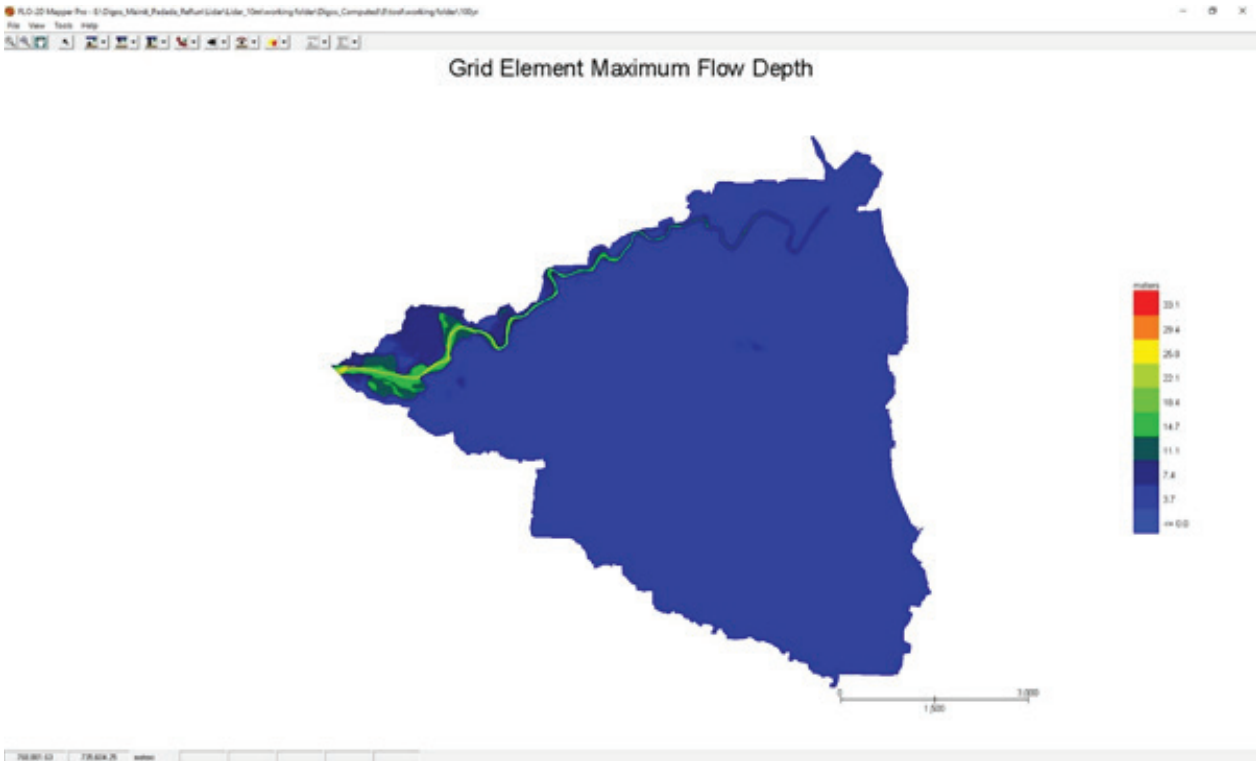


Figure 59. Generated 100-year rain return flow depth map from FLO-2D Mapper

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 58.36890 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The generated hazard map for Digos is in Figures 58.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 43894900.00 m2. The generated flow depth map for Digos is in Figures 59.

There is a total of 34088534.89 m3 of water entering the model. Of this amount, 15257043.87 m3 is due to rainfall while 18831491.02 m3 is inflow from other areas outside the model. 6156764.50 m3 of this water is lost to infiltration and interception, while 19224428.46 m3 is stored by the flood plain. The rest, amounting up to 8707324.78 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Digos HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 60 shows the comparison between the two discharge data.

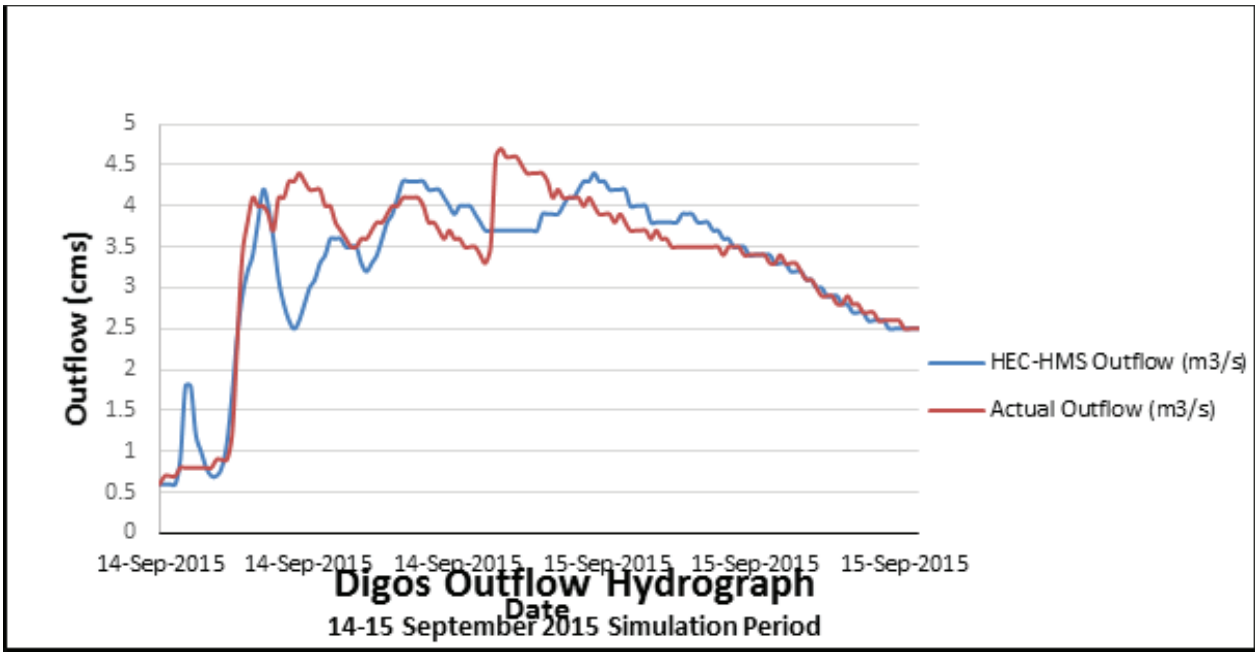


Figure 60. Outflow Hydrograph of Digos produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 28 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 28. Range of Calibrated Values for Digos River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve Number	Initial Abstraction (mm)	0.3328 – 24.26
			Curve Number	36.566 – 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.0167 – 0.396
			Storage Coefficient (hr)	0.0167 – 1.1
	Baseflow	Recession	Recession Constant	0.13 - 1
			Ratio to Peak	0.06 – 0.34
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0715

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.3328 mm to 24.26 mm means that there is a small initial fraction of the storm depth after which runoff begins, increasing the river outflow.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

For Digos, the basin consists mainly of shrublands and cultivated areas and the soil consists of mostly undifferentiated land and clay loam.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.0167 hours to 1.1 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 values within the range of 0.13 to 1 indicate that the discharge leaving every subbasin within Digos recede differ significantly. Values of ratio to peak within the range of 0.06 to 0.34 indicate a much steeper receding limb of the outflow hydrograph.

Manning's roughness coefficients correspond to the common roughness of Philippine watersheds. Digos river basin reaches' Manning's coefficient is 0.0715, showing that the catchment is mostly filled with floodplains with heavy brushlands (Brunner, 2010).

Table 29. Summary of the Efficiency Test of Digos HMS Model

Accuracy Measure	Value
RMSE	0.99
R2	0.98
NSE	0.76
PBIAS	1.90
RSR	0.49

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.991 (m3/s).

The Pearson correlation coefficient (r2) 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 0.983.

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 0.760.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 1.904.

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 0.490.

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

5.7.1 Hydrograph Using the Rainfall Runoff Model

The summary graph (Figure 61) shows the Digos outflow using the Davao Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (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.

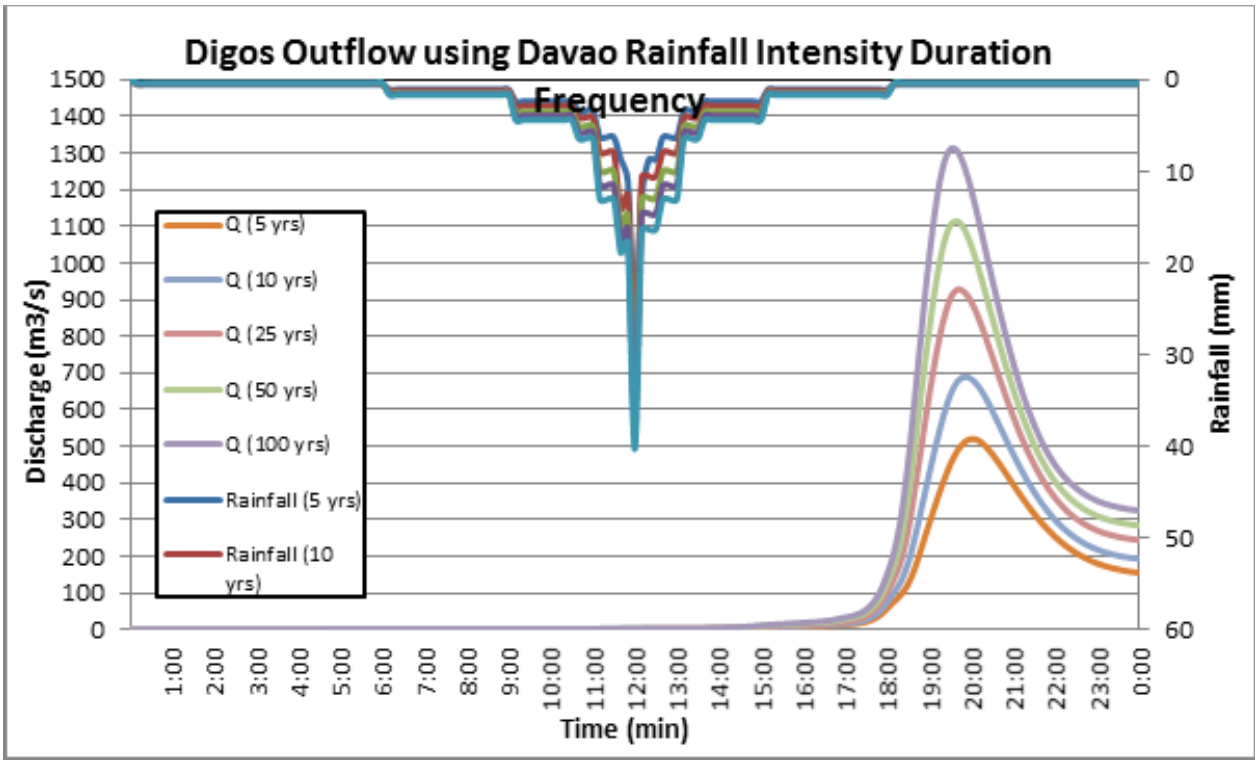


Figure 61. Outflow hydrograph at Digos Station generated using Davao RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Digos discharge using the Davao Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 30.

Table 30. Outflow hydrograph at Digos Station generated using Davao RIDF simulated in HEC-HMS

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (cms)	Time to Peak
5-Year	121.1	25.1	520.2	8 hours
10-Year	140.7	28.8	689.3	7 hours, 50 minutes
25-Year	165.5	33.5	928.1	7 hours, 40 minutes
50-Year	183.9	37	1114.6	7 hours, 40 minutes
100-Year	202.1	40.5	1310.9	7 hours, 30 minutes

5.7.2 Discharge data using Dr. Horritt's hydrologic method

The river discharge values for the three rivers entering the floodplain are shown in Figure 62 to Figure 71 and the peak values are summarized in Table 31 to Table 40.

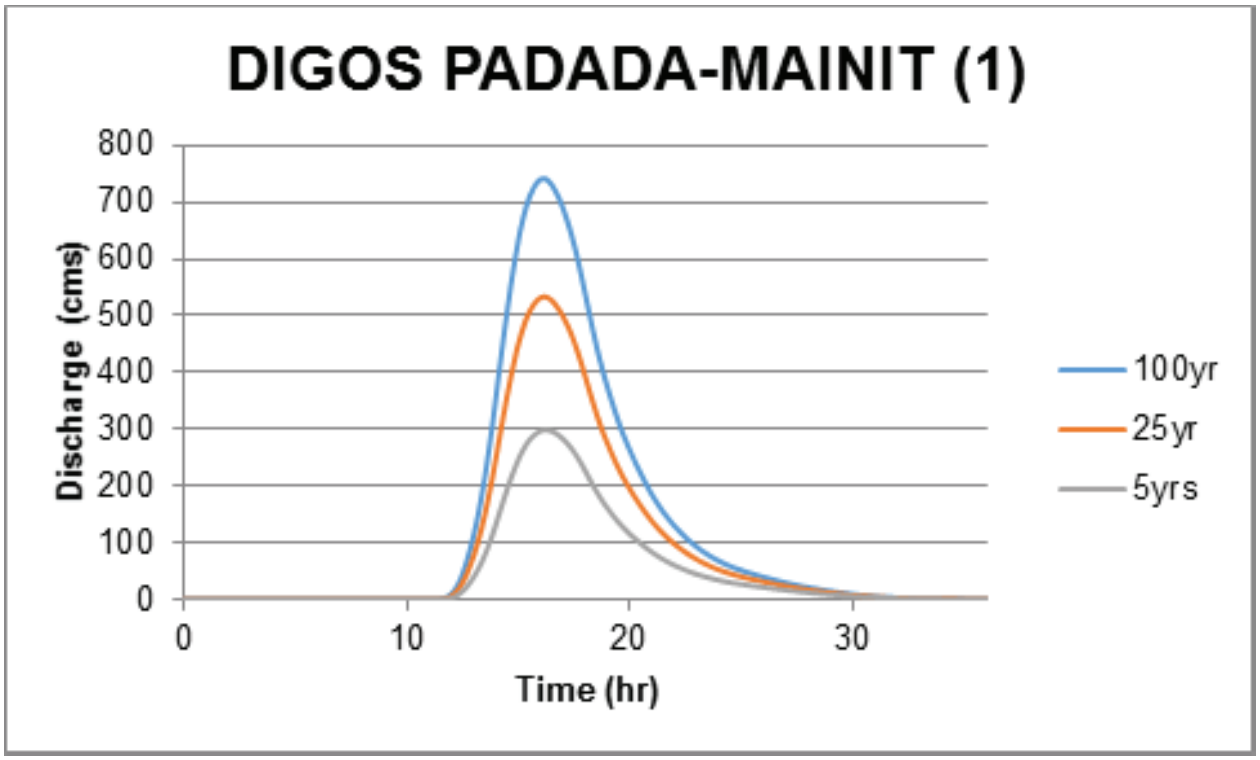


Figure 62. Digos Padada-Mainit river (1) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

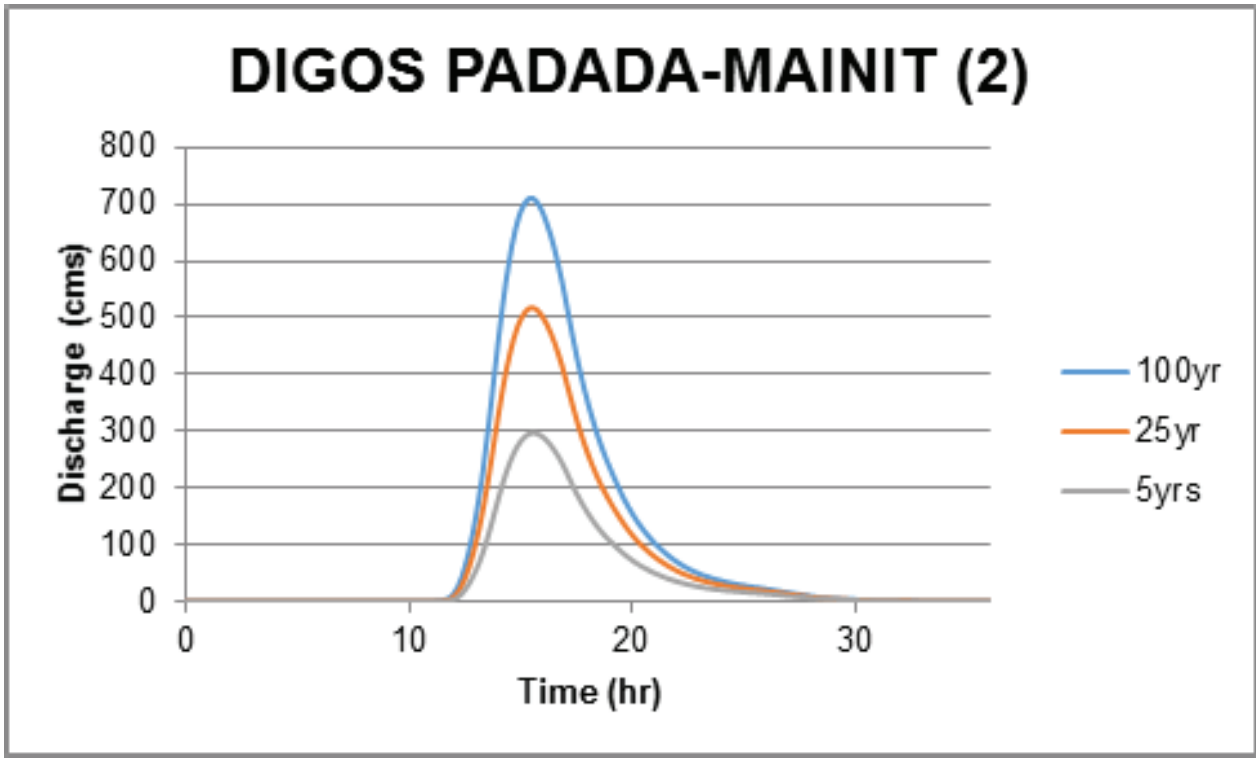


Figure 63. Digos Padada-Mainit river (2) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

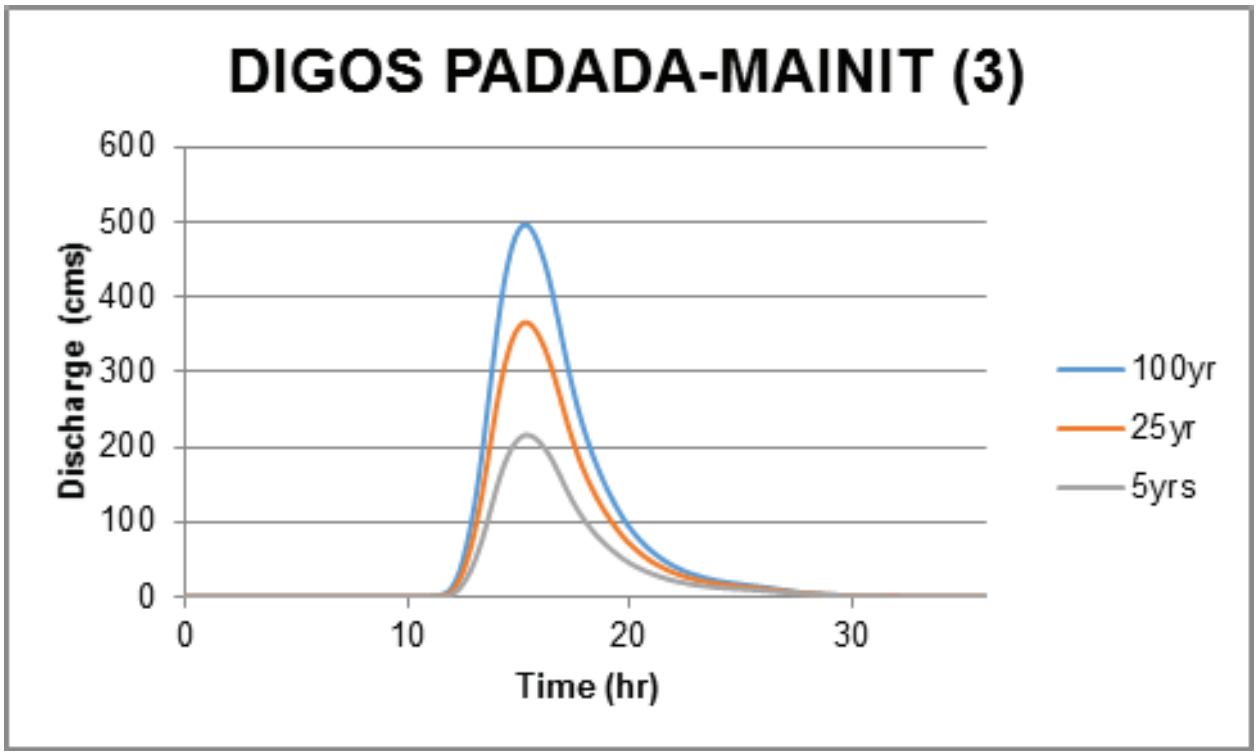


Figure 64. Digos Padada-Mainit river (3) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

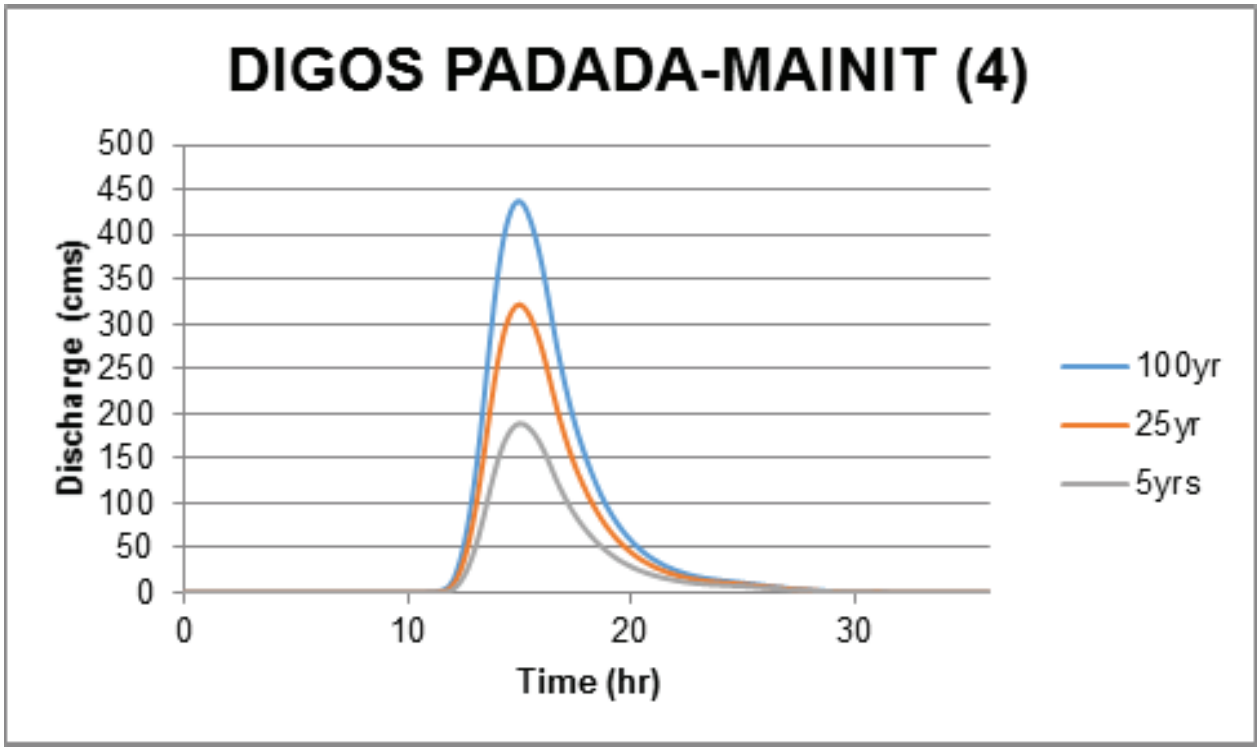


Figure 65. Digos Padada-Mainit river (4) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-

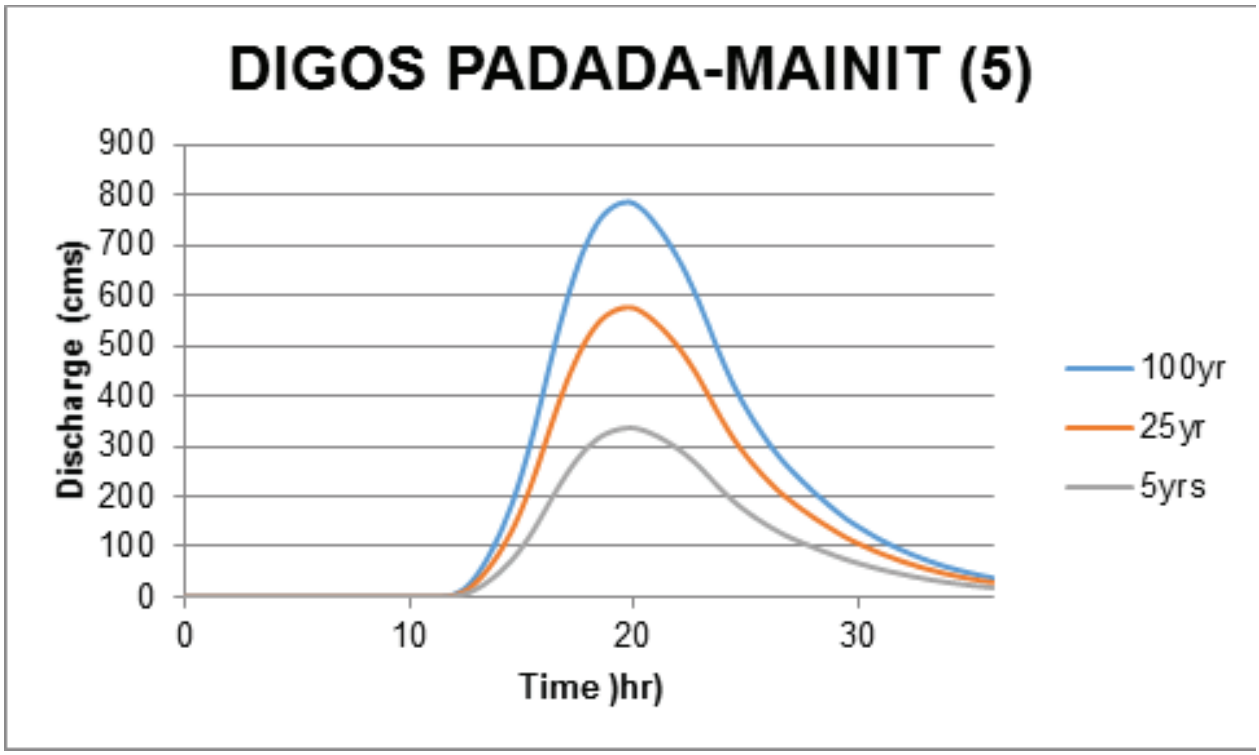


Figure 66. Digos Padada-Mainit river (5) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-

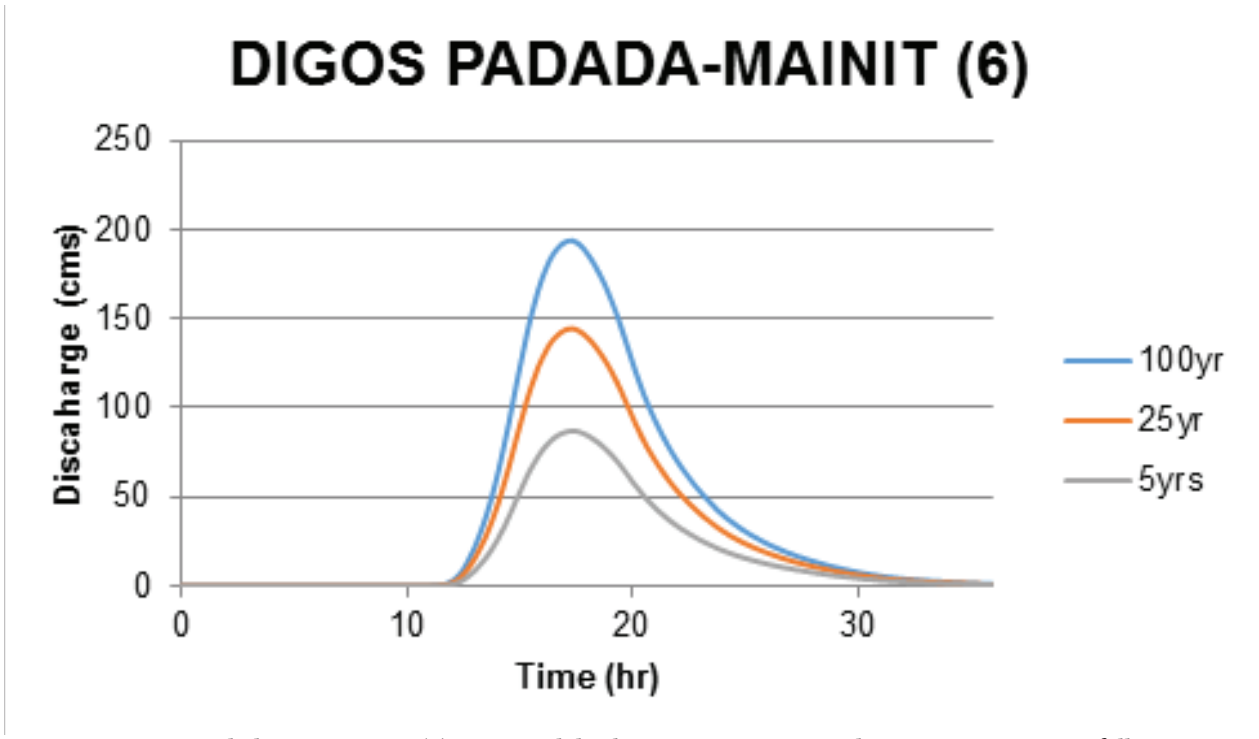


Figure 67. Digos Padada-Mainit river (6) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

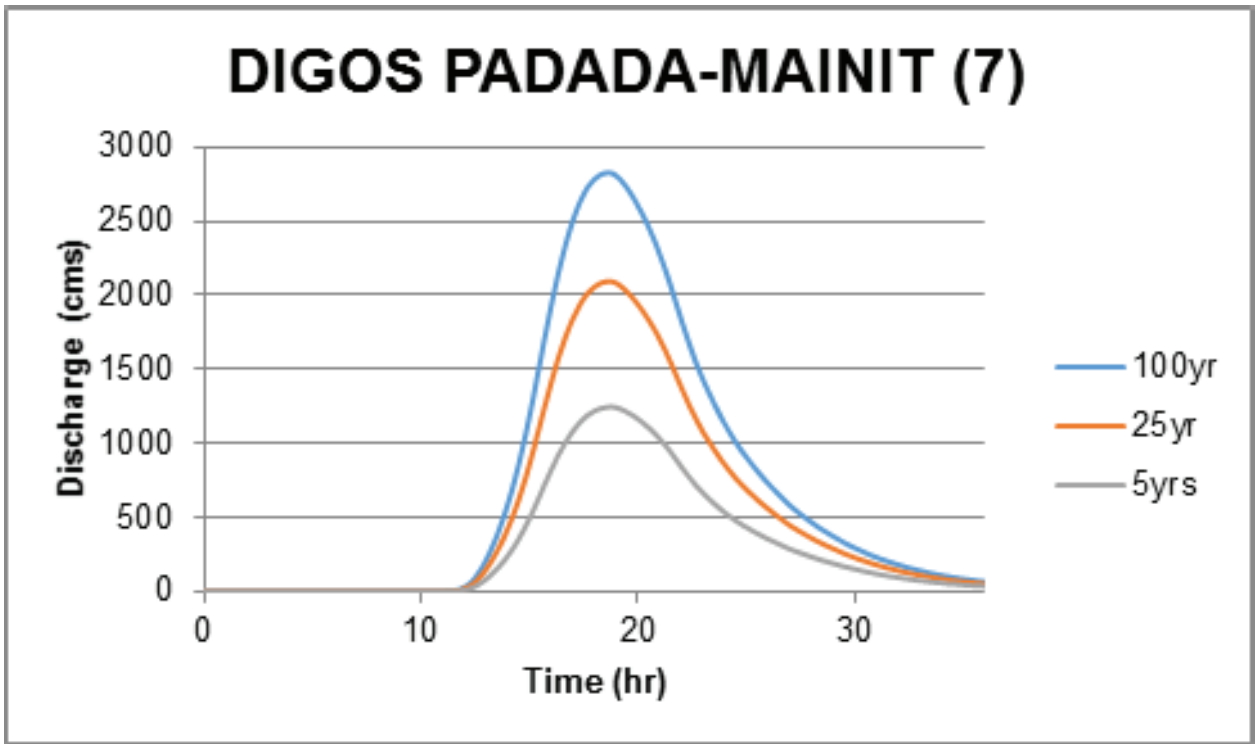


Figure 68. Digos Padada-Mainit river (7) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

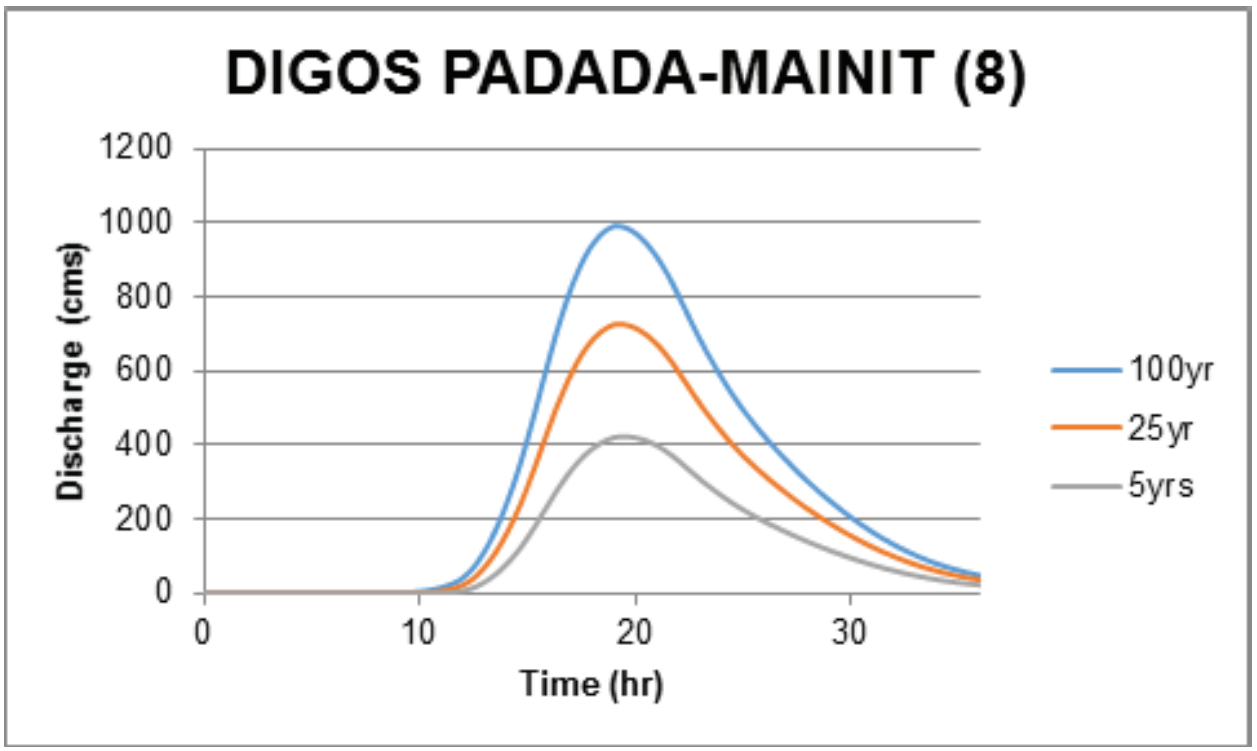


Figure 69. Digos Padada-Mainit river (8) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

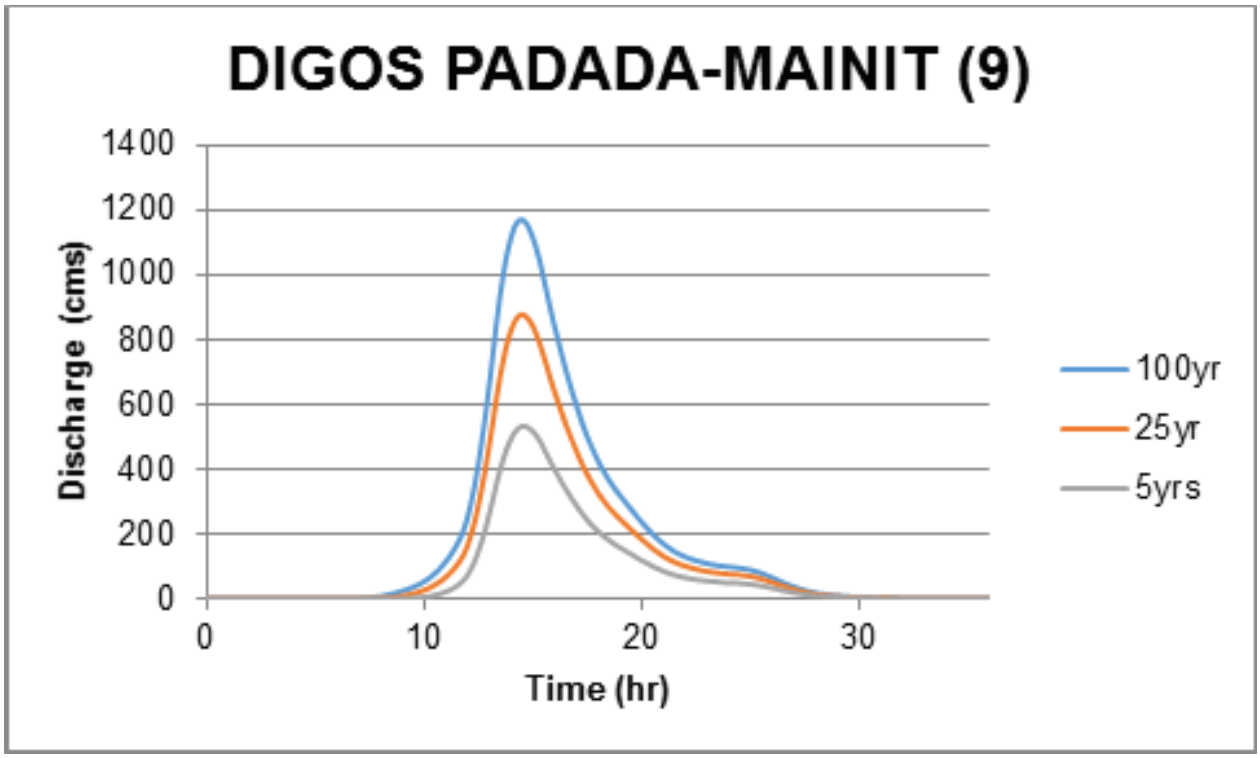


Figure 70. Digos Padada-Mainit river (9) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

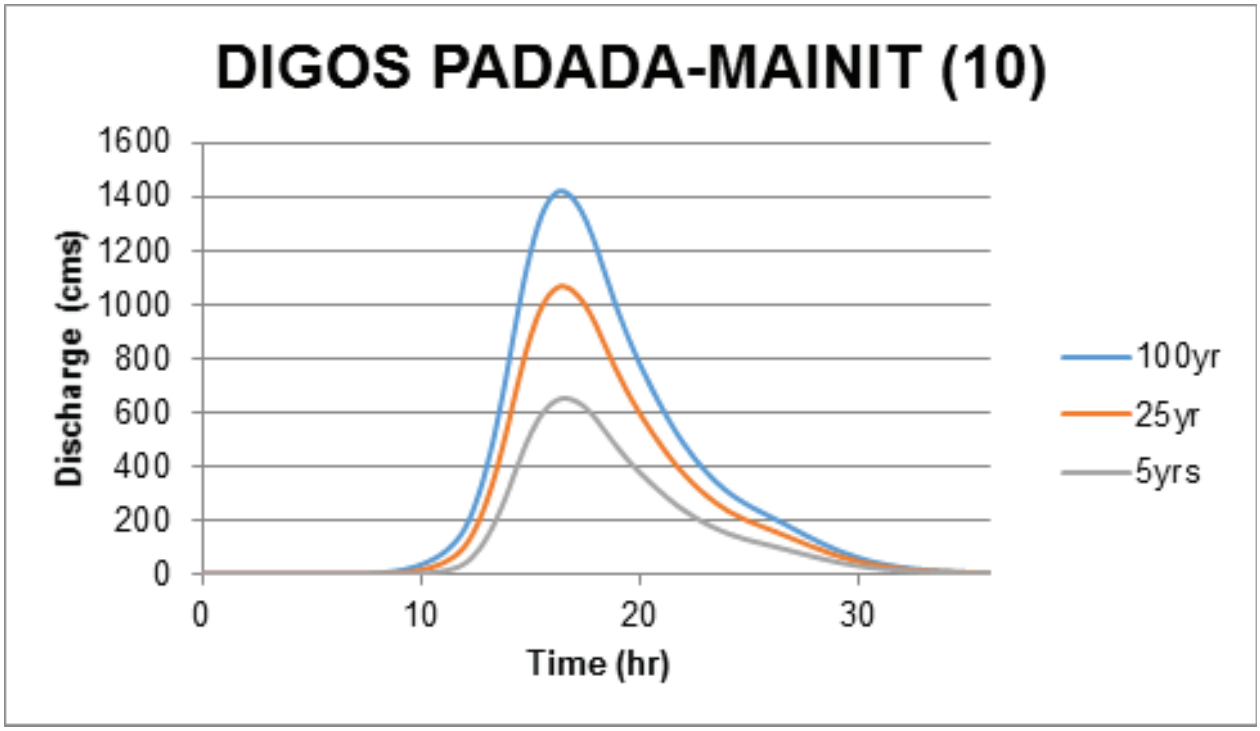


Figure 71. Digos Padada-Mainit river (10) generated discharge using 5-, 25-, and 100-year GenSan rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 31. Summary of Digos Padada-Mainit river (1) discharge generated in HEC-HMS

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

Table 32. Summary of Digos Padada-Mainit river (2) discharge generated in HEC-HMS

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

Table 33. Summary of Digos Padada-Mainit river (3) discharge generated in HEC-HMS

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

Table 34. Summary of Digos Padada-Mainit river (4) discharge generated in HEC-HMS

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

Table 35. Summary of Digos Padada-Mainit river (5) discharge generated in HEC-HMS

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

Table 36. Summary of Digos Padada-Mainit river (6) discharge generated in HEC-HMS

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

Table 37. Summary of Digos Padada-Mainit river (7) discharge generated in HEC-HMS

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

Table 38. Summary of Digos Padada-Mainit river (8) discharge generated in HEC-HMS

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

Table 39. Summary of Digos Padada-Mainit river (9) discharge generated in HEC-HMS

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

Table 40. Summary of Digos Padada-Mainit river (10) discharge generated in HEC-HMS

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

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 41.

Table 41. Validation of river discharge estimates

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

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

5.8 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown, since only the UPM-FMC base flow was calibrated. The sample generated map of Digos River using the calibrated HMS base flow is shown in Figure 72.

Figure 72. Sample output of Digos RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 73 to Figure 78 shows the 5-, 25-, and 100-year rain return scenarios of the Digos floodplain.

The generated flood hazard maps for the Digos Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAG-ASA for hazard maps - “Low”, “Medium”, and “High” - the affected institutions were given their individual assessment for each Flood Hazard Scenario (5 yr, 25 yr, and 100 yr). Table 42 shows the percentage of area affected by flooding per municipality.

Table 42. Municipalities affected in Digos Floodplain

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

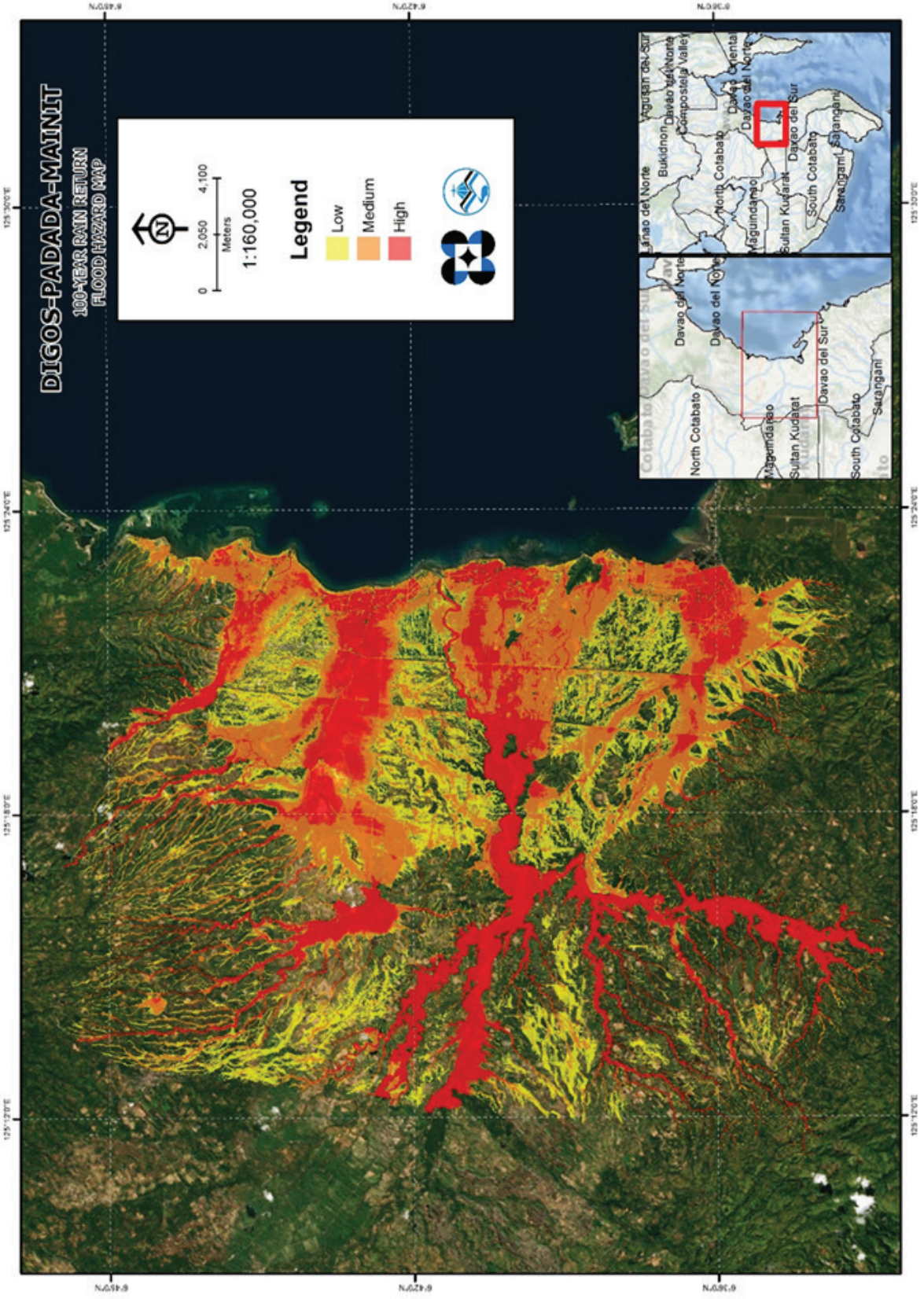


Figure 73. 100-year Flood Hazard Map for Digos Floodplain

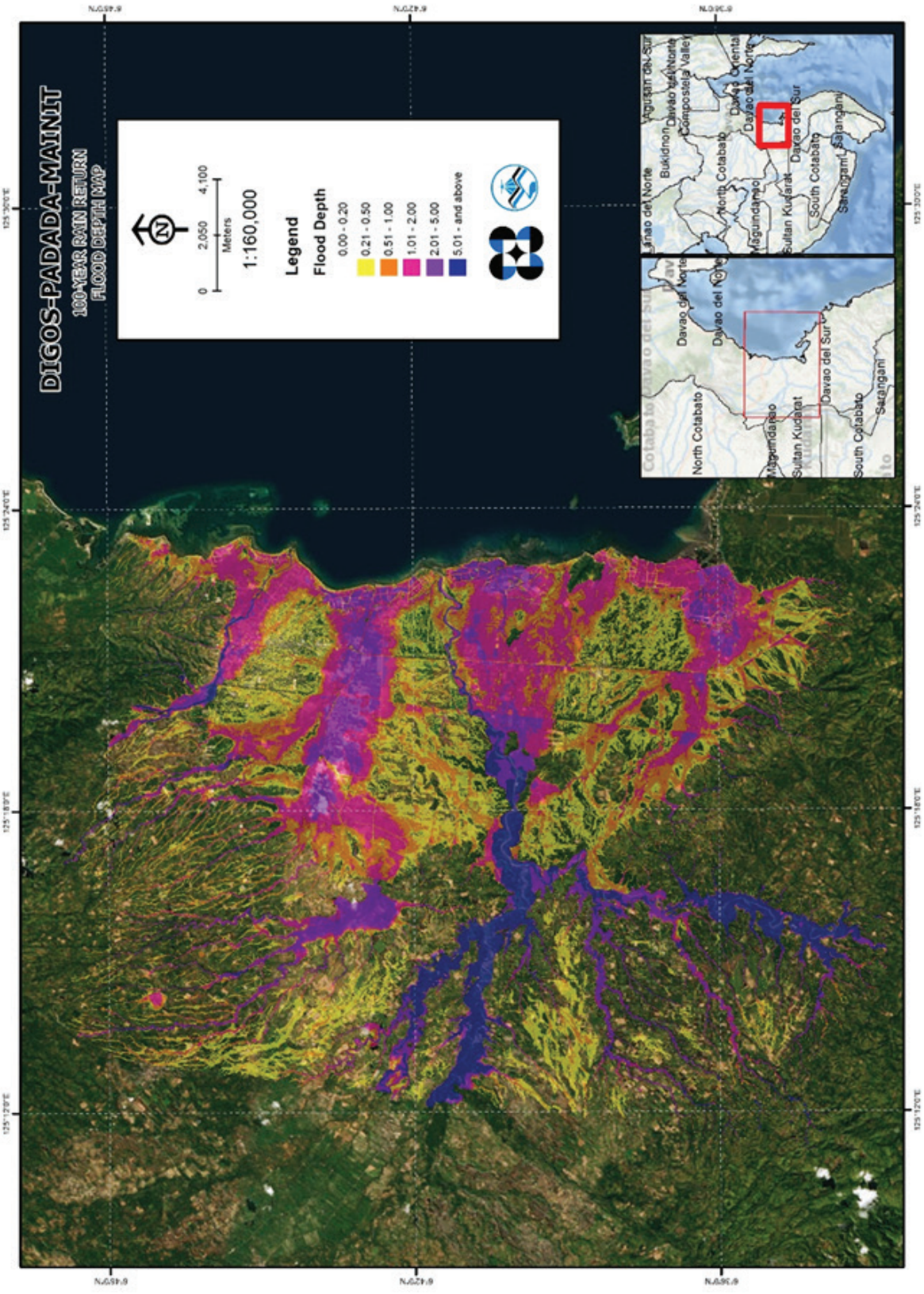


Figure 74. 100-year Flow Depth Map for Digos Floodplain

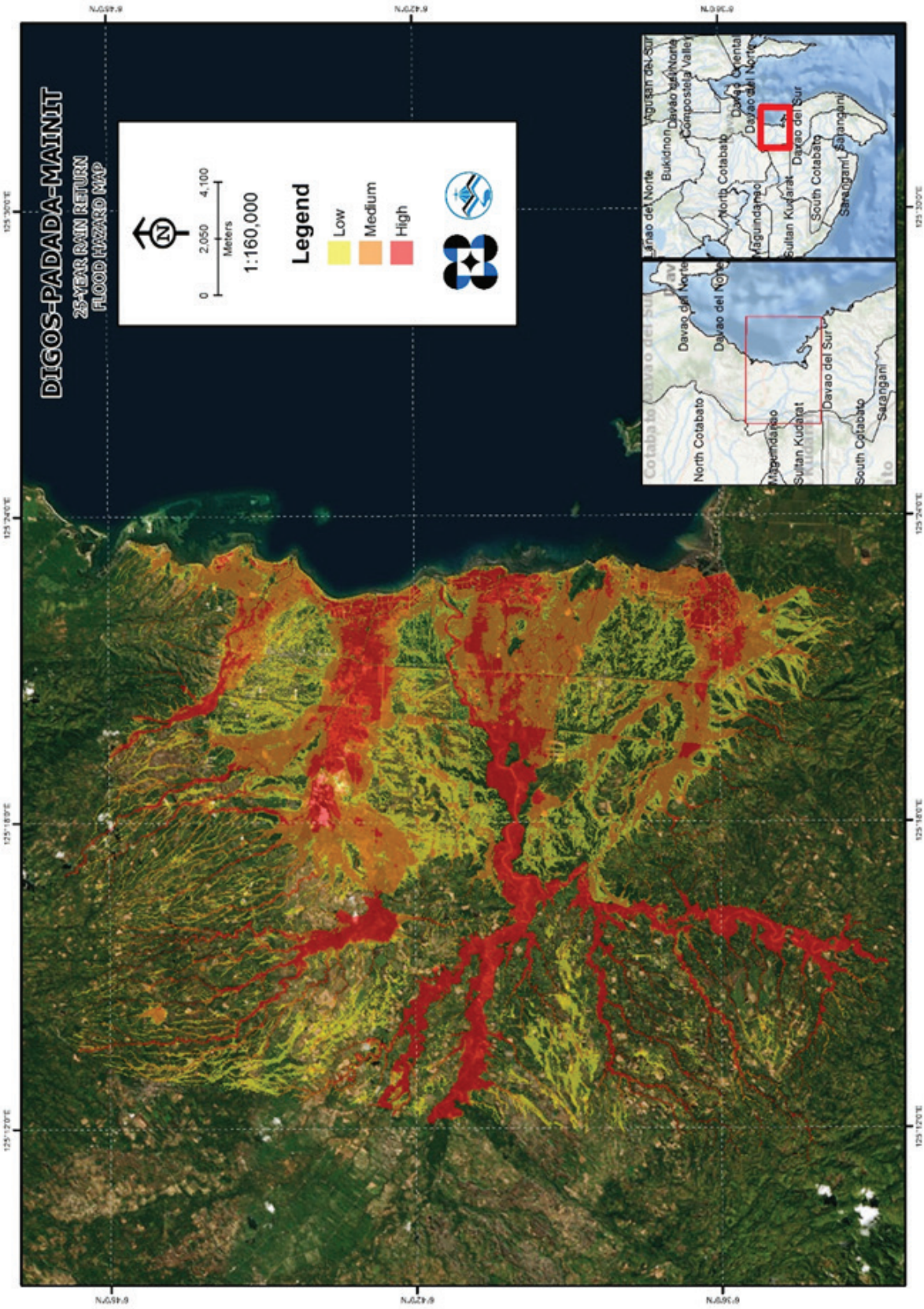


Figure 75. 25-year Flood Hazard Map for Digos Floodplain

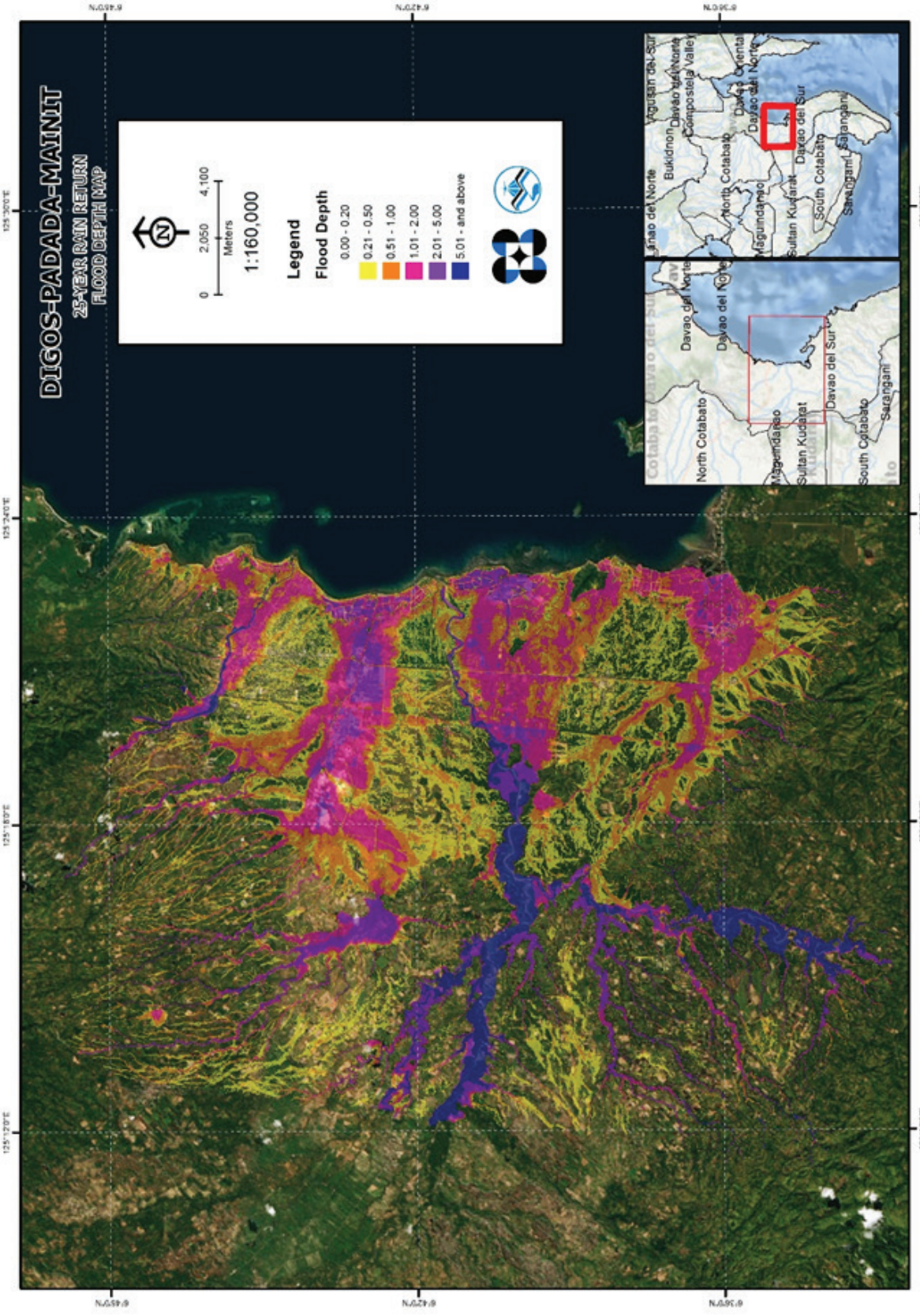


Figure 76. 25-year Flow Depth Map for Digos Floodplain

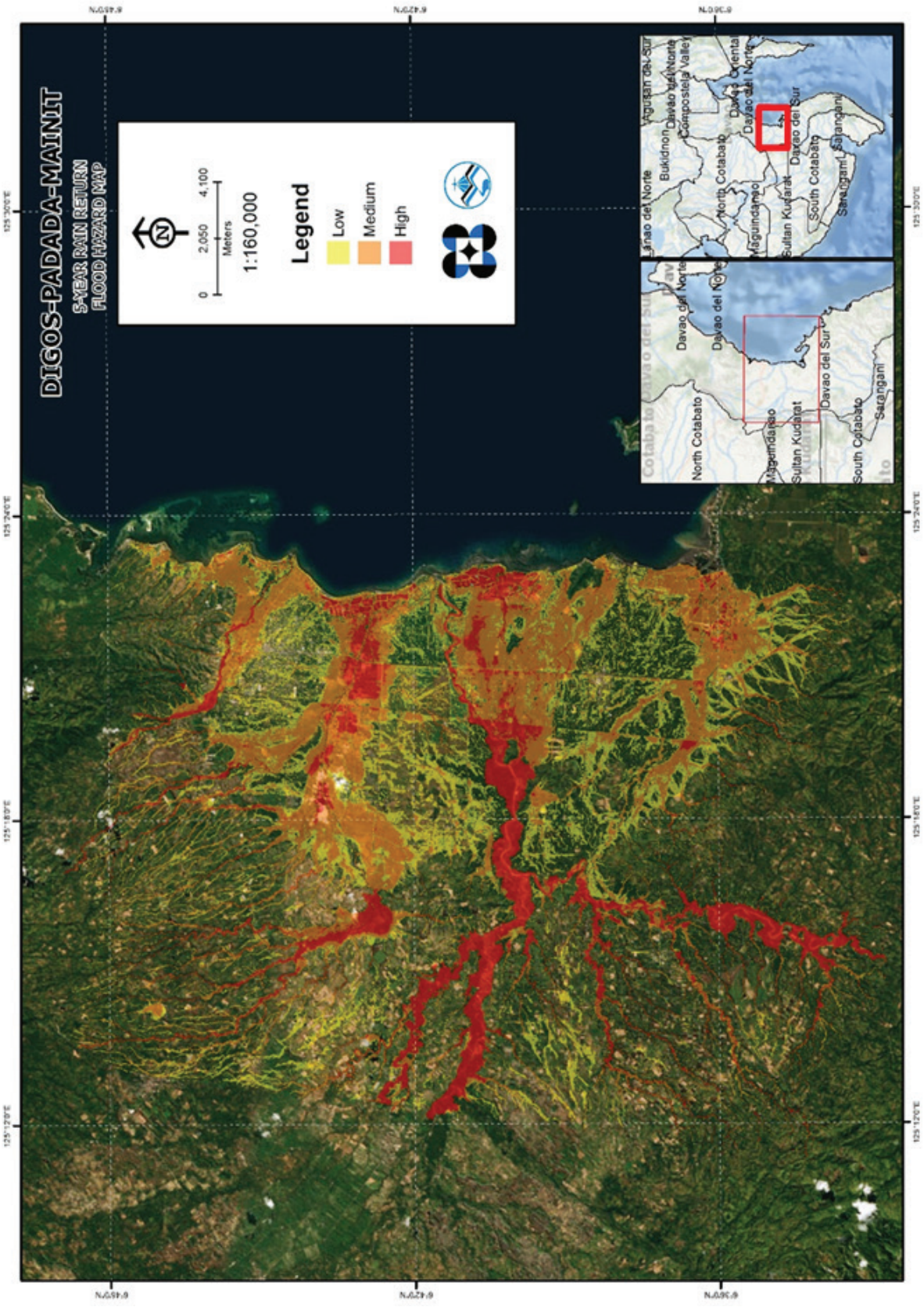


Figure 77. 5-year Flood Hazard Map for Digos Floodplain

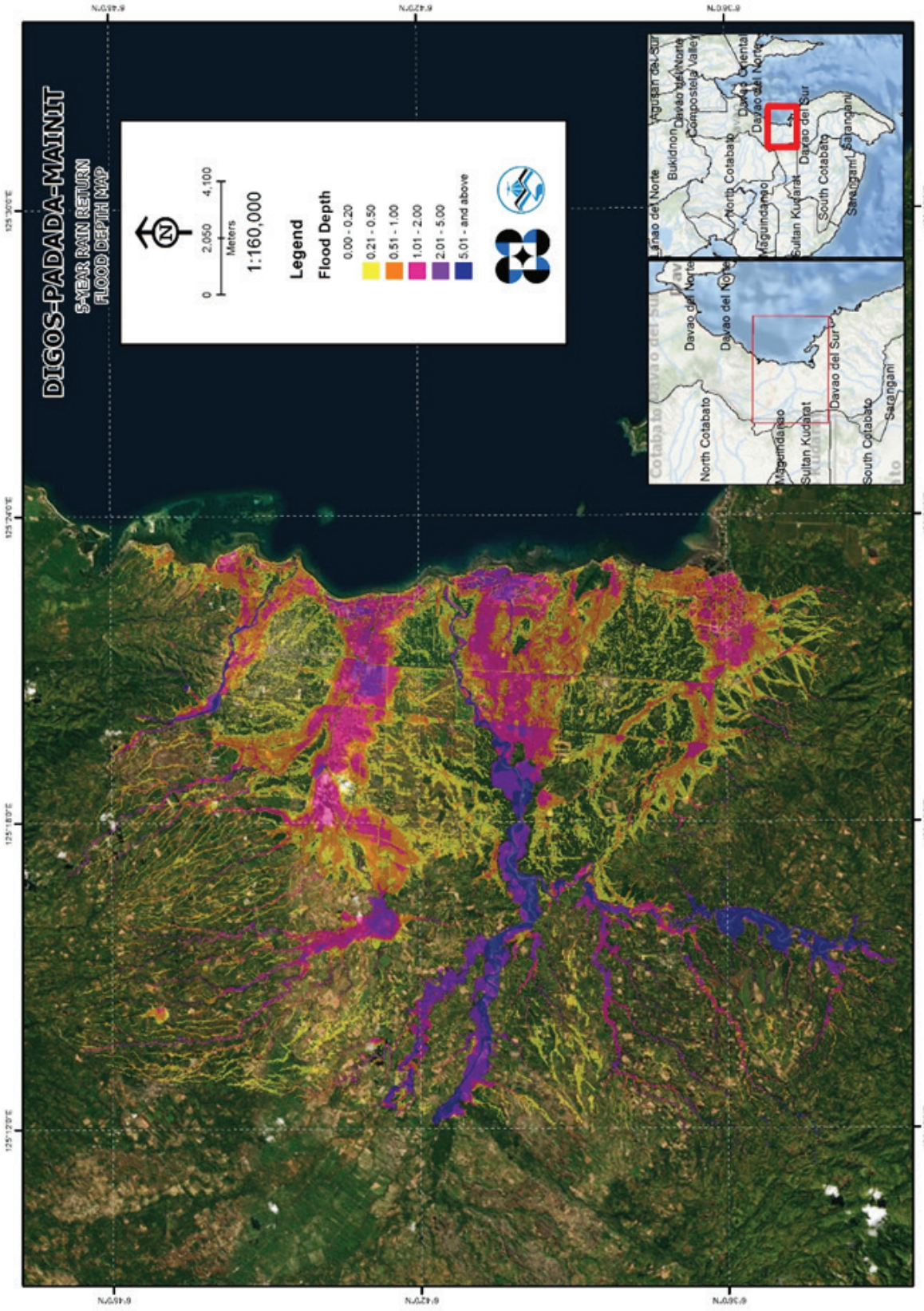


Figure 78. 5-year Flood Depth Map for Digos Floodplain

5.10 Inventory of Areas Exposed to Flooding

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

For the 5-year return period, 11.95% of the municipality of Bansalan with an area of 136.18 sq. km. will experience flood levels of less than 0.20 meters. 1.83% of the area will experience flood levels of 0.21 to 0.50 meters while 0.71%, 0.26%, and 0.11% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

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

DIGOS - PADADA BASIN		Affected Barangays in Bansalan (in sq. m.)							
		Anonang	Bonifacio	Buenavista	Mabunga	New Clarin	Poblacion	Poblacion Dos	Union
Affected Area (sq. km.)	0-0.20	1.68	1.41	2.22	4.30	0.57	1.404	1.50	3.20
	0.21-0.50	0.12	0.12	0.26	1.022	0.047	0.18	0.39	0.35
	0.51-1.00	0.066	0.039	0.13	0.18	0.0508	0.105	0.10	0.28
	1.01-2.00	0.0207	0.016	0.036	0.107	0.038	0.042	0.019	0.079
	2.01-5.00	0.0004	0.0071	0.014	0.027	0.00504	0.053	0	0.049
	> 5.00	0	0	0	0	0	0.0002	0	0.0007

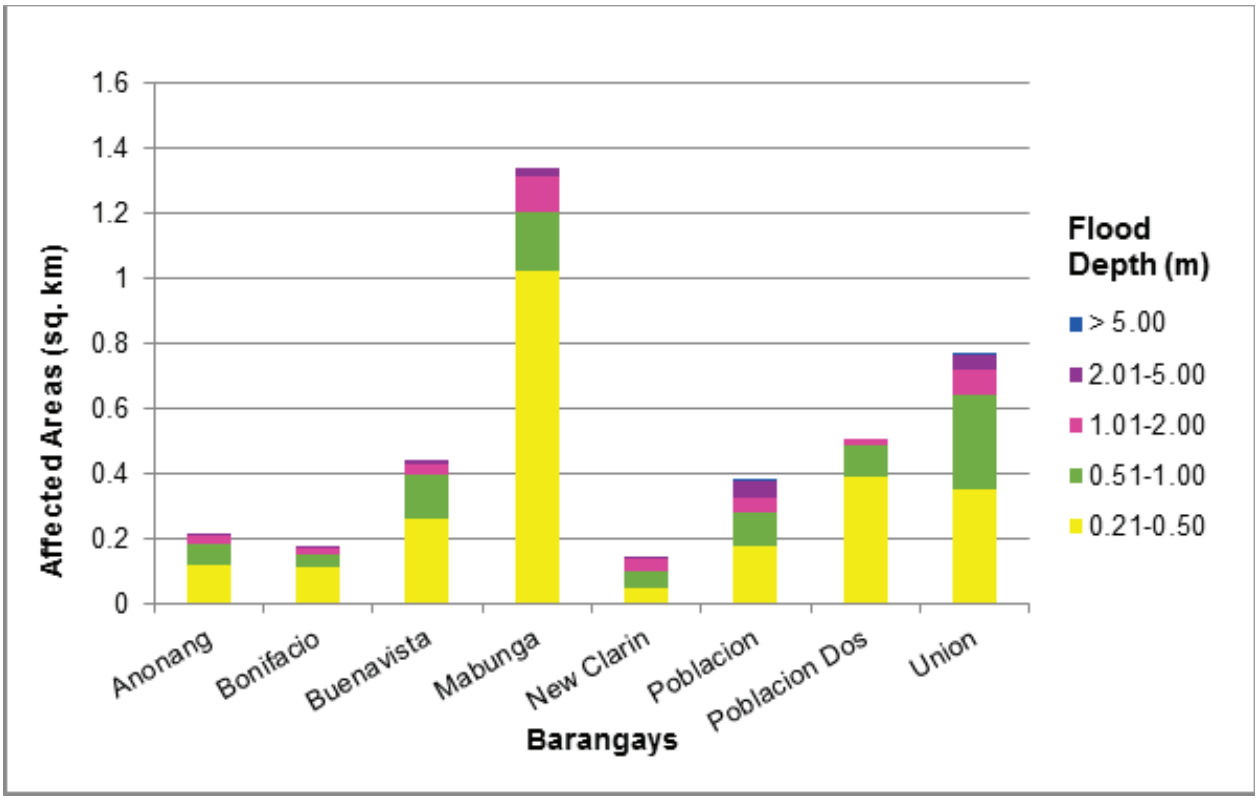


Figure 79. Affected Areas in Bansalan, Davao del Sur during 5-Year Rainfall Return Period

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

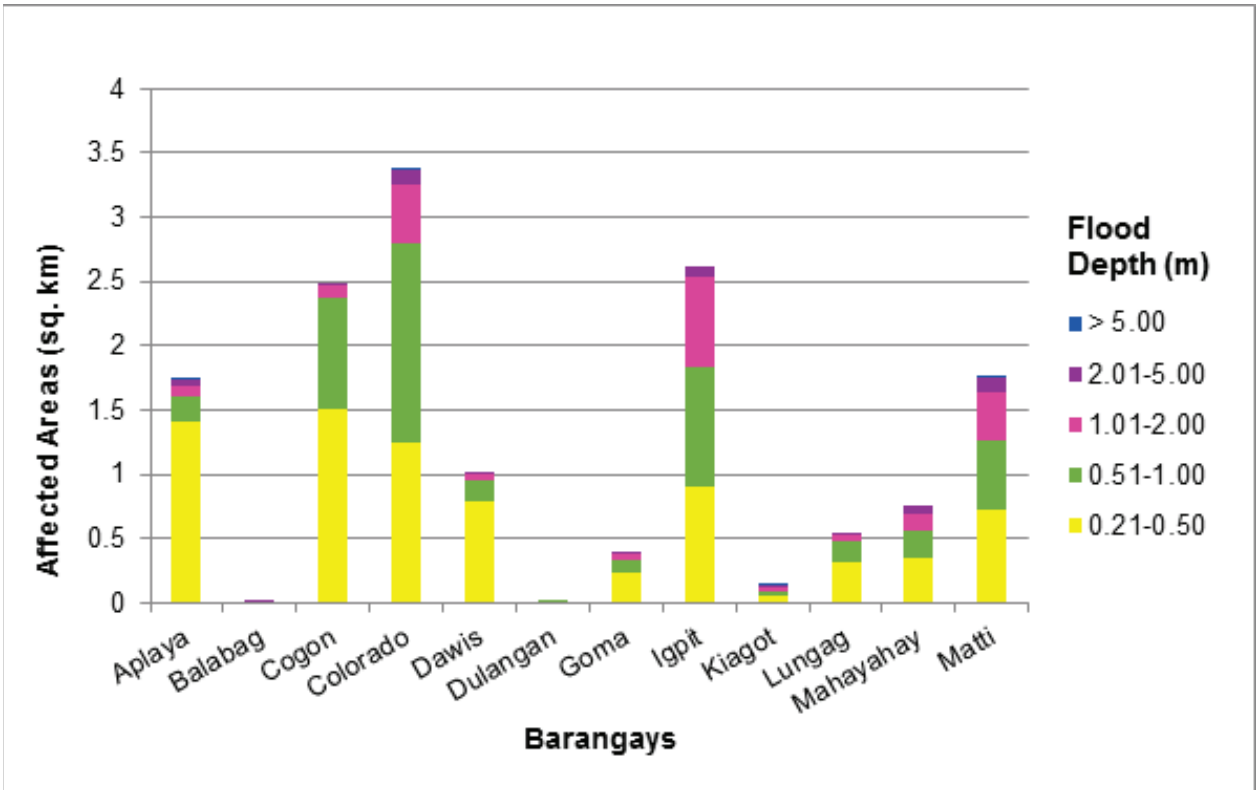


Figure 80. Affected Areas in Digos City, Davao del Sur during 5-Year Rainfall Return Period

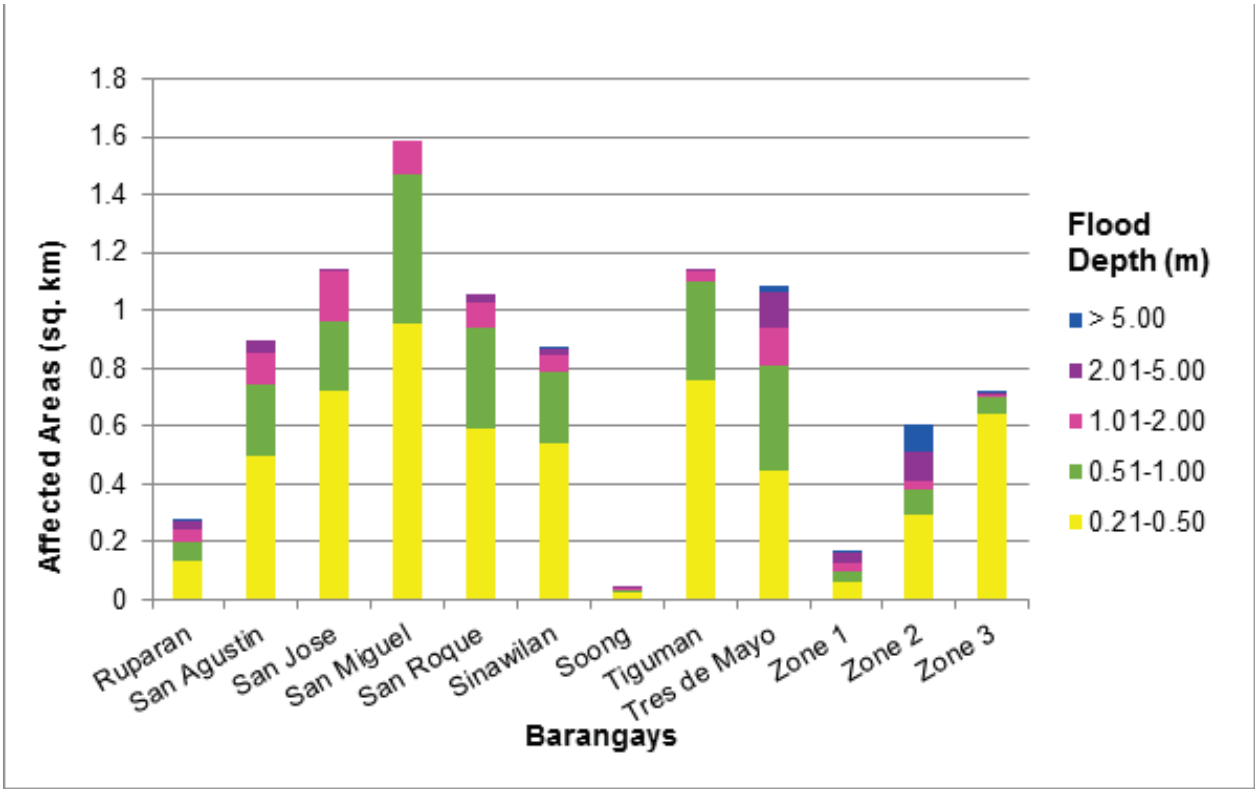


Figure 81. Affected Areas in Digos City, Davao del Sur during 5-Year Rainfall Return Period

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

DIGOS - PADADA BASIN		Affected Barangays in Digos City											
		Aplaya	Balabag	Cogon	Colorado	Dawis	Dulangan	Goma	Igpit	Kiagot	Lungag	Mahayahay	Matti
Affected Area (sq. km.)	0-0.20	1.68	1.41	2.22	4.3	0.57	1.4	1.5	3.2	1.95	4.79	4.38	5.01
	0.21-0.50	0.12	0.12	0.26	1.02	0.047	0.18	0.39	0.35	0.057	0.32	0.36	0.73
	0.51-1.00	0.066	0.039	0.13	0.18	0.051	0.11	0.1	0.28	0.029	0.15	0.21	0.54
	1.01-2.00	0.021	0.016	0.036	0.11	0.038	0.042	0.019	0.079	0.032	0.056	0.12	0.37
	2.01-5.00	0.0004	0.0071	0.014	0.027	0.005	0.053	0	0.049	0.014	0.006	0.069	0.13
	> 5.00	0	0	0	0	0	0.0002	0	0.0007	0.0003	0	0	0.0026

DIGOS - PADADA BASIN		Affected Barangays in Digos City											
		Ruparan	San Agustin	San Jose	San Miguel	San Roque	Sinawilan	Soong	Tiguman	Tres de Mayo	Zone 1	Zone 2	Zone 3
Affected Area (sq. km.)	0-0.20	3.12	4.52	1.8	1.17	5.34	3.58	0.8	1.56	2.29	2.16	1.02	2.06
	0.21-0.50	0.13	0.5	0.72	0.95	0.59	0.54	0.023	0.76	0.45	0.064	0.29	0.64
	0.51-1.00	0.069	0.25	0.24	0.51	0.35	0.25	0.01	0.34	0.37	0.037	0.088	0.061
	1.01-2.00	0.041	0.1	0.18	0.12	0.092	0.057	0.0072	0.03	0.13	0.028	0.032	0.0082
	2.01-5.00	0.033	0.044	0.002	0	0.029	0.023	0.0035	0.0003	0.12	0.034	0.099	0.0058
	> 5.00	0.0022	0	0	0	0	0.0081	0	0	0.025	0.0017	0.096	0.0095

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

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

DIGOS - PADADA BASIN		Affected Barangays in Hagonoy										
		Balutakay	**Clib**	**Guihing**	**Guihing Aplaya**	**Hagonoy Crossing**	**Kibuaya**	**La Union**	**Lanuro**	**Lapulabao**	**Leling**	**Mahayahay**
Affected Area (sq. km.)	0-0.20	0.84	2.53	1.63	3.37	1.89	1.66	3.19	1.72	2.98	6.12	1.75
	0.21-0.50	0.63	0.35	0.58	1.48	0.64	1.03	0.26	1.06	1.22	3.14	0.61
	0.51-1.00	0.8	0.36	0.1	0.33	0.08	1.94	0.19	0.62	0.55	1.79	0.08
	1.01-2.00	1.67	0.13	0.025	0.093	0.032	1	0.14	0.74	0.095	2.34	0.015
	2.01-5.00	0.57	0.07	0.078	0.053	0.17	0.34	0.048	0.00034	0.011	0.39	0.0072
	> 5.00	0	0.018	0.09	0.0018	0.077	0	0.01	0	0.0021	0	0.0003

DIGOS - PADADA BASIN		Affected Barangays in Hagonoy									
		Malabang Damsite	**Maliit Digos**	**New Quezon**	**Paligue**	**Poblacion**	**Sacub**	**San Guillermo**	**San Isidro**	**Sinayawan**	**Tologan**
Affected Area (sq. km.)	0-0.20	2.46	1.6	2.88	0.78	2.72	4.1	0.81	0.093	1.27	1.06
	0.21-0.50	0.27	0.37	0.43	0.4	0.86	2.47	0.22	0.25	0.82	0.22
	0.51-1.00	0.23	0.72	0.28	0.14	0.1	0.37	0.4	0.78	0.67	0.057
	1.01-2.00	0.075	0.18	0.56	0.017	0.066	0	0.2	1.16	0.25	0.036
	2.01-5.00	0.047	0.019	0.85	0	0.028	0	0.12	0.23	0	0.045
	> 5.00	0.0001	0.0002	0	0	0.012	0	0	0	0	0.096

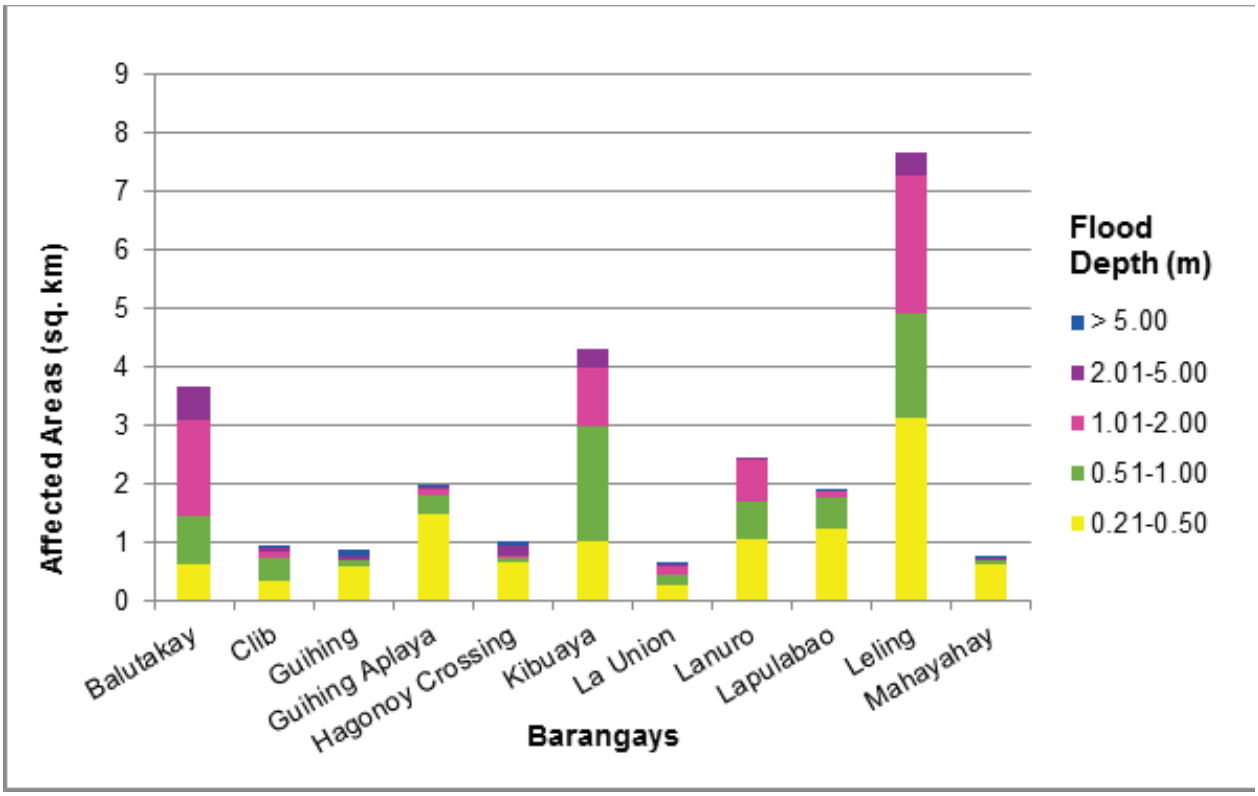


Figure 82. Affected Areas in Hagonoy, Davao del Sur during 5-Year Rainfall Return Period

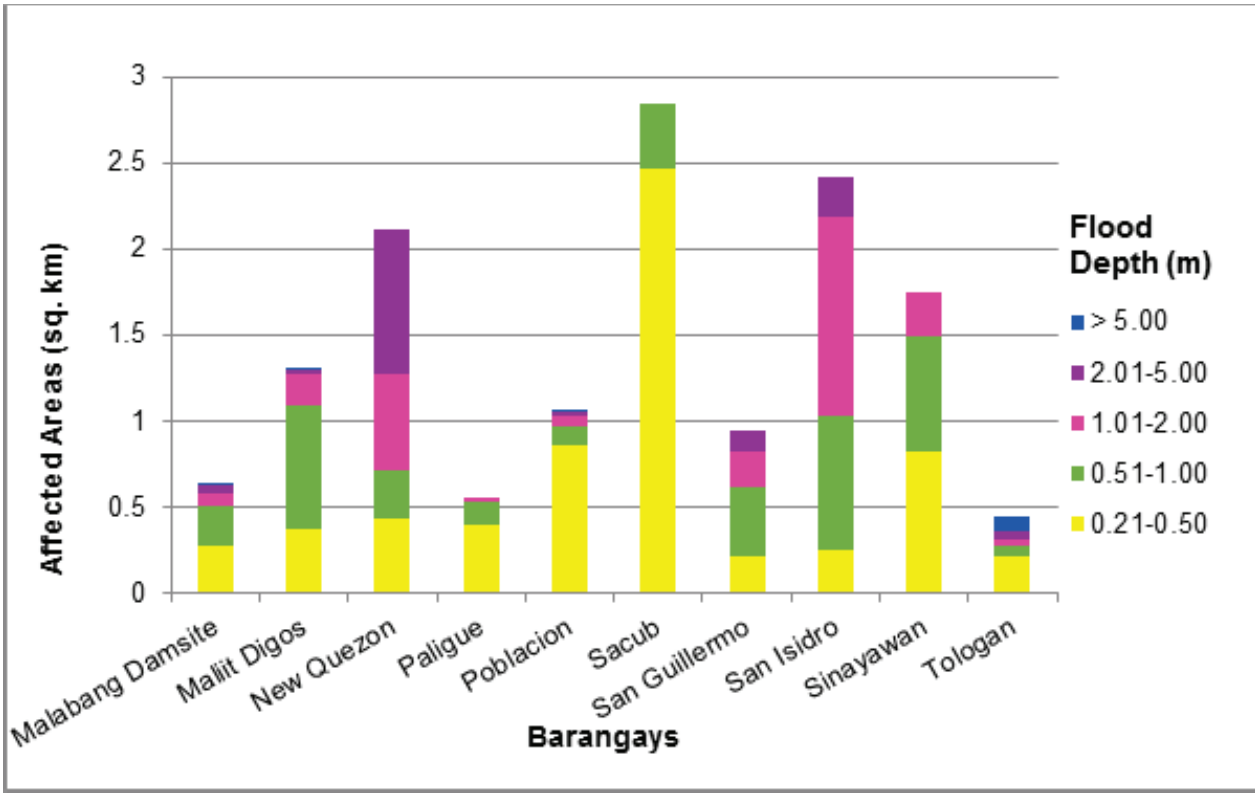


Figure 83. Affected Areas in Hagonoy, Davao del Sur during 5-Year Rainfall Return Period

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

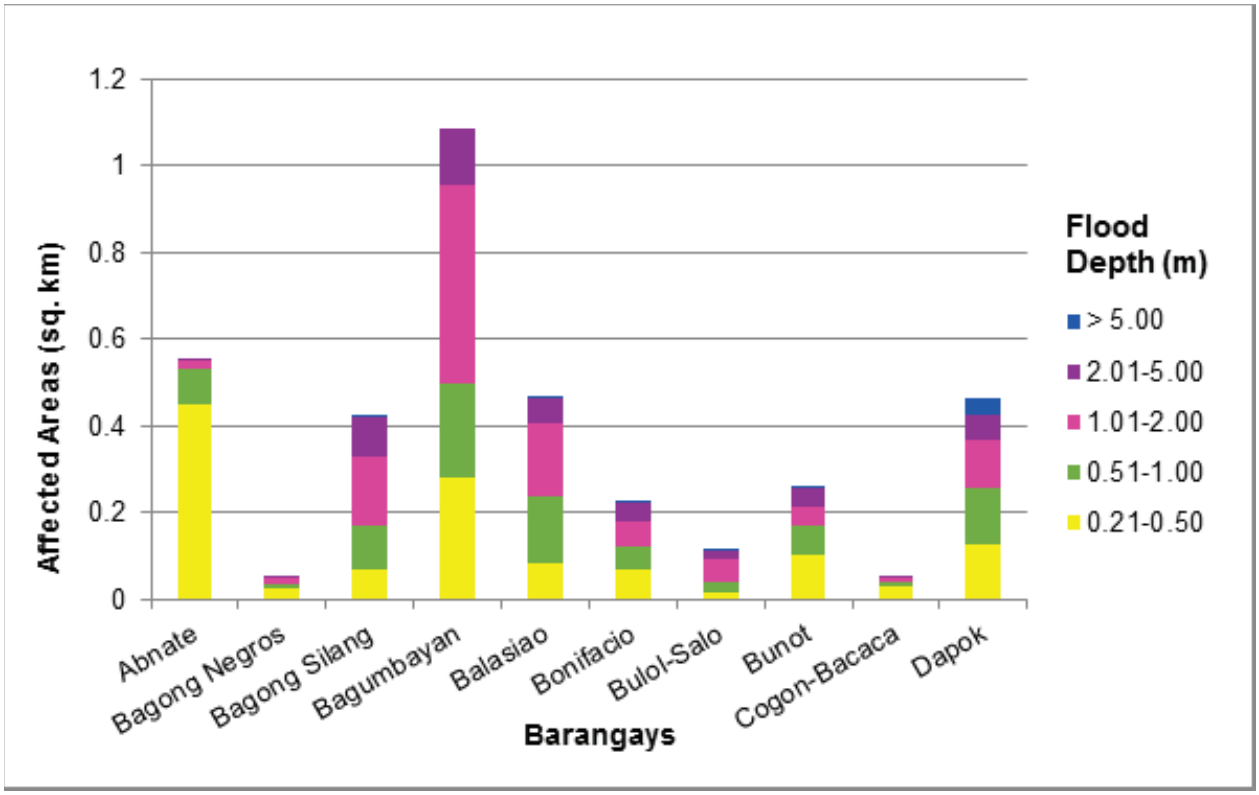


Figure 84. Affected Areas in Kiblawan, Davao del Sur during 5-Year Rainfall Return Period

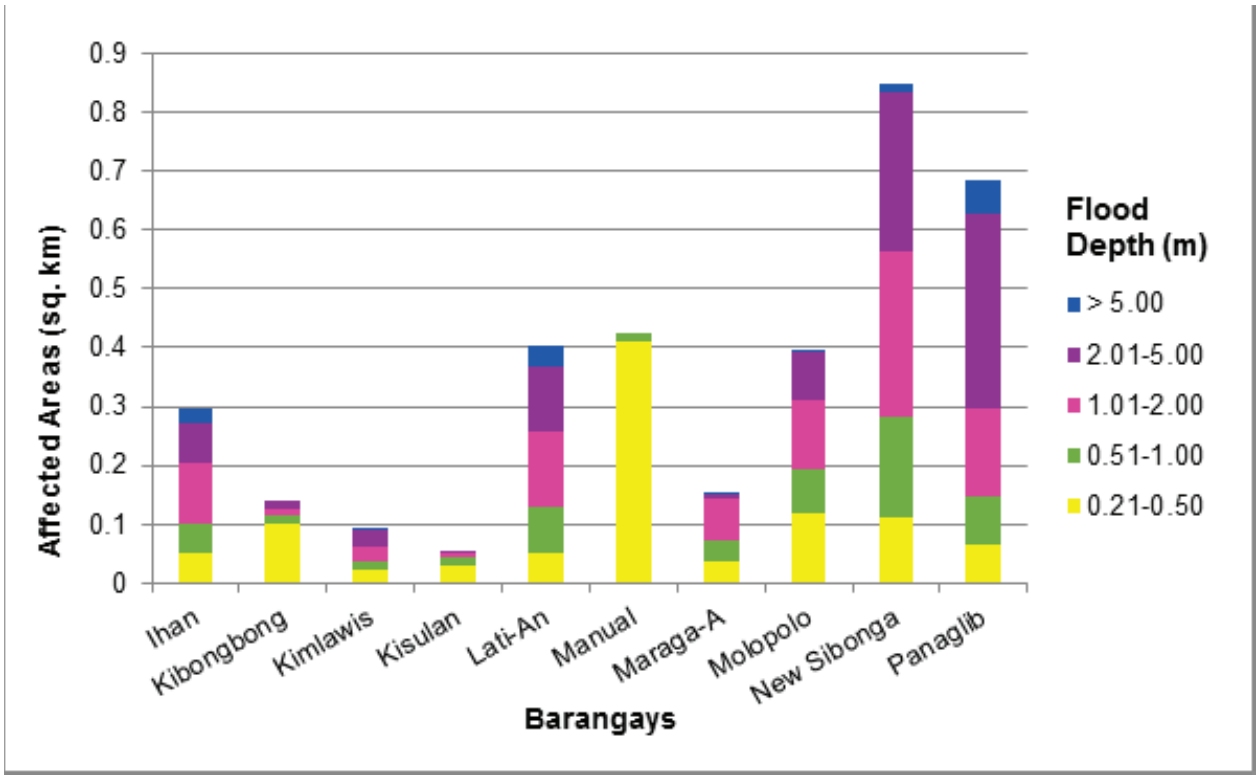


Figure 85. Affected Areas in Kiblawan, Davao del Sur during 5-Year Rainfall Return Period

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

DIGOS - PADADA BASIN		Affected Barangays in Kiblawan									
		Abnate	Bagong Negros	Bagong Silang	Bagumbayan	Balasiao	Bonifacio	Bulol-Salo	Bunot	Cogon-Bacaca	Dapok
Affected Area (sq. km.)	0-0.20	2.83	1.29	1.38	4.98	1.71	2.31	0.9	2.7	0.59	1.73
	0.21-0.50	0.45	0.027	0.07	0.28	0.083	0.072	0.018	0.1	0.03	0.13
	0.51-1.00	0.081	0.011	0.1	0.22	0.16	0.052	0.021	0.07	0.0087	0.13
	1.01-2.00	0.021	0.011	0.16	0.45	0.17	0.055	0.052	0.043	0.01	0.11
	2.01-5.00	0.0001	0.0031	0.092	0.13	0.059	0.045	0.022	0.041	0.0059	0.062
	> 5.00	0	0	0.0021	0	0.0023	0.0026	0.0004	0.0073	0	0.035

DIGOS - PADADA BASIN		Affected Barangays in Kiblawan									
		Ihan	Kibongbong	Kimlawis	Kisulan	Lati-An	Manual	Maraga-A	Molopolo	New Sibonga	Panaglib
Affected Area (sq. km.)	0-0.20	0.51	0.78	1.41	0.89	1.21	1.32	1.47	2.45	1.57	0.5
	0.21-0.50	0.052	0.1	0.022	0.03	0.052	0.41	0.038	0.12	0.11	0.066
	0.51-1.00	0.051	0.013	0.017	0.014	0.078	0.015	0.034	0.074	0.17	0.08
	1.01-2.00	0.1	0.012	0.024	0.0078	0.13	0	0.07	0.12	0.28	0.15
	2.01-5.00	0.067	0.015	0.027	0.0032	0.11	0	0.011	0.084	0.27	0.33
	> 5.00	0.024	0	0.0035	0	0.035	0	0.0006	0.0002	0.012	0.057

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

DIGOS - PADADA BASIN		Affected Barangays in Kiblawan									
		Pasig	Poblacion	Pocaleel	San Isidro	San Jose	San Pedro	Santo Niño	Tacub	Tacul	Waterfall
Affected Area (sq. km.)	0-0.20	0.59	1.71	1.2	1.33	0.8	3.35	1.15	1.46	0.93	0.71
	0.21-0.50	0.029	0.048	0.046	0.22	0.057	0.41	0.043	0.25	0.29	0.17
	0.51-1.00	0.022	0.025	0.095	0.027	0.041	0.13	0.046	0.027	0.045	0.024
	1.01-2.00	0.05	0.034	0.13	0.06	0.067	0.19	0.12	0.048	0.0087	0.0018
	2.01-5.00	0.011	0.037	0.036	0.066	0.084	0.067	0.25	0.03	0.0005	0.00031
	> 5.00	0	0.0027	0	0.00026	0.013	0	0.00034	0.0008	0	0

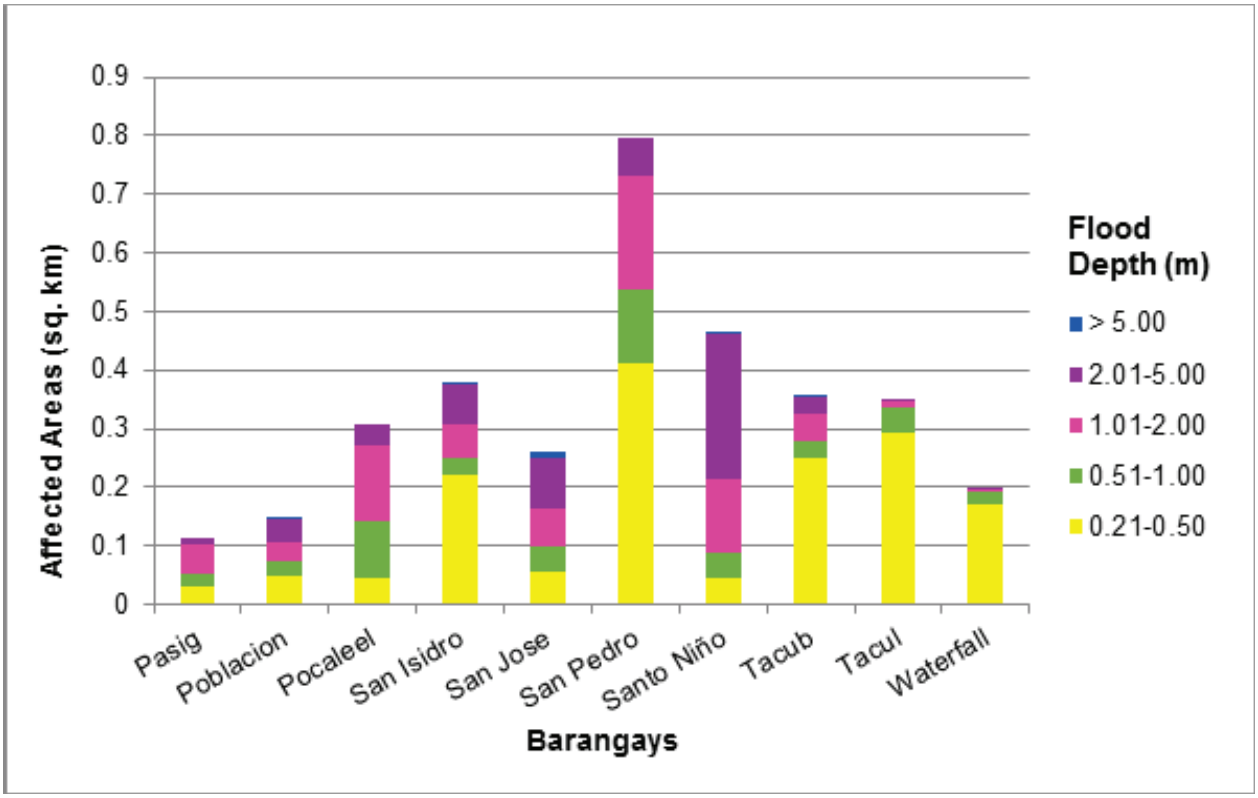


Figure 86. Affected Areas in Kiblawan, Davao del Sur during 5-Year Rainfall Return Period

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

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

DIGOS - PADADA BASIN		Affected Barangay in Magsaysay
		New Ilocos
Affected Area (sq. km.)	0-0.20	0.36
	0.21-0.50	0.04
	0.51-1.00	0.015
	1.01-2.00	0.0098
	2.01-5.00	0.0008
	> 5.00	0

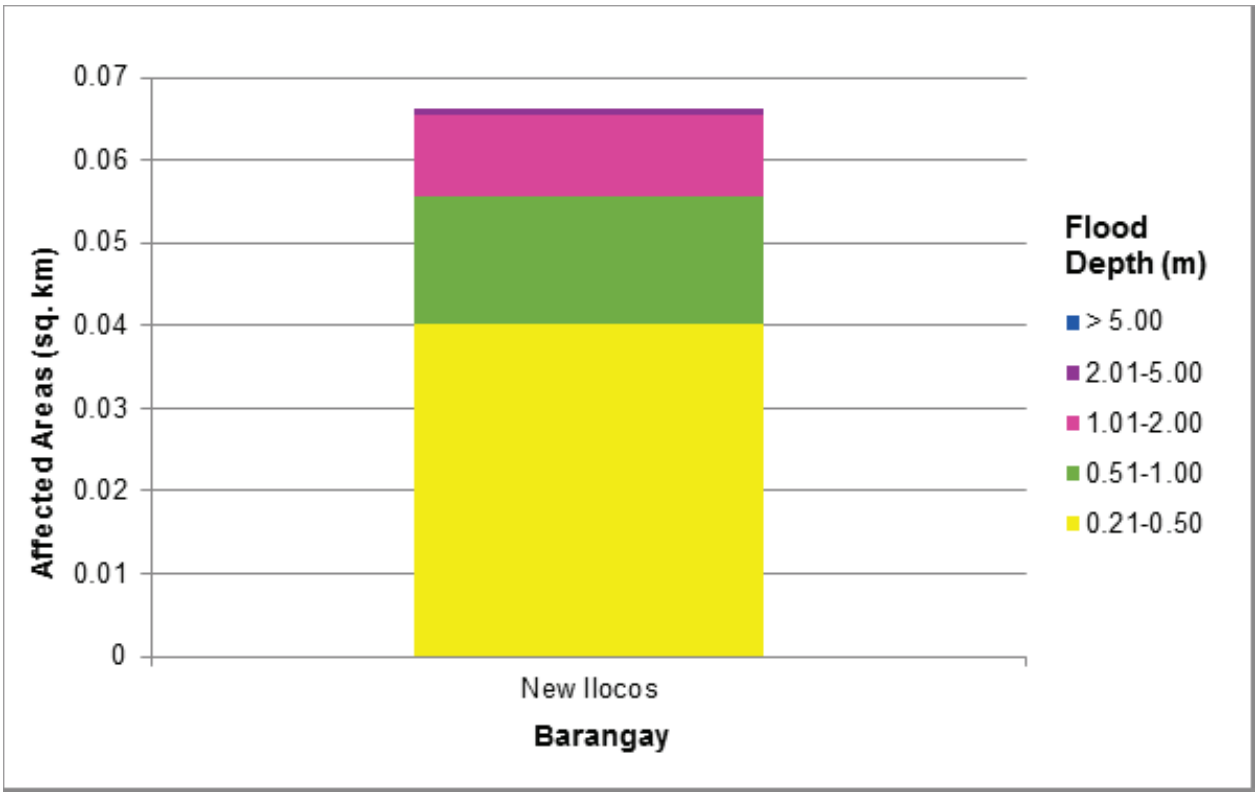


Figure 87. Affected Areas in Magsaysay, Davao del Sur during 5-Year Rainfall Return Period

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

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

DIGOS - PADADA BASIN		Affected Barangays in Malalag					
		Bagumbayan	**Bolton**	**Kiblagon**	**Lapu-Lapu**	**Mabini**	**New Baclayon**
Affected Area (sq. km.)	0-0.20	0.018	0.59	13.37	31.26	1.38	2.48
	0.21-0.50	0.0079	0.074	3.95	1.61	0.032	0.67
	0.51-1.00	0.005	0.018	2.64	1.36	0.018	0.77
	1.01-2.00	0.00082	0.012	1.35	1.54	0.0094	0.24
	2.01-5.00	0	0.0081	0.17	1	0.013	0.0068
	> 5.00	0	0.0003	0.0089	0.07	0.0042	0

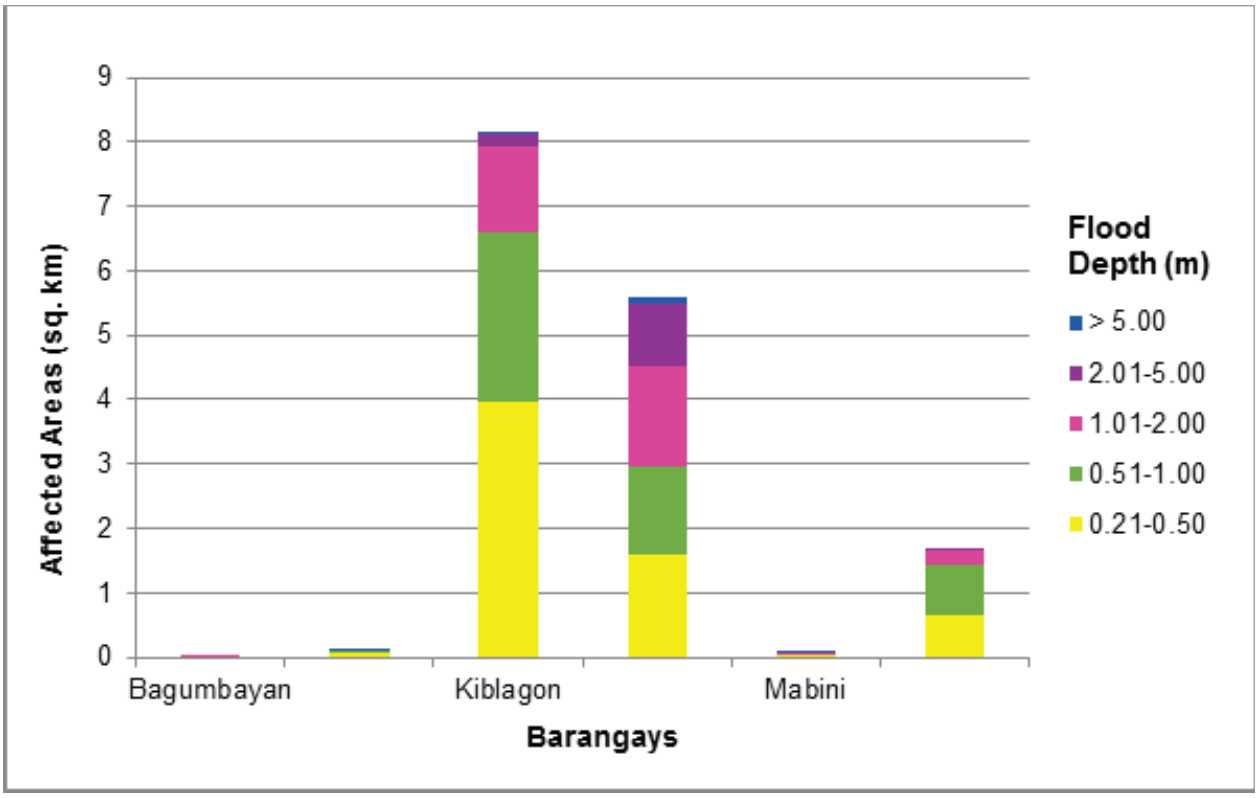


Figure 88. Affected Areas in Malalag, Davao del Sur during 5-Year Rainfall Return Period

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

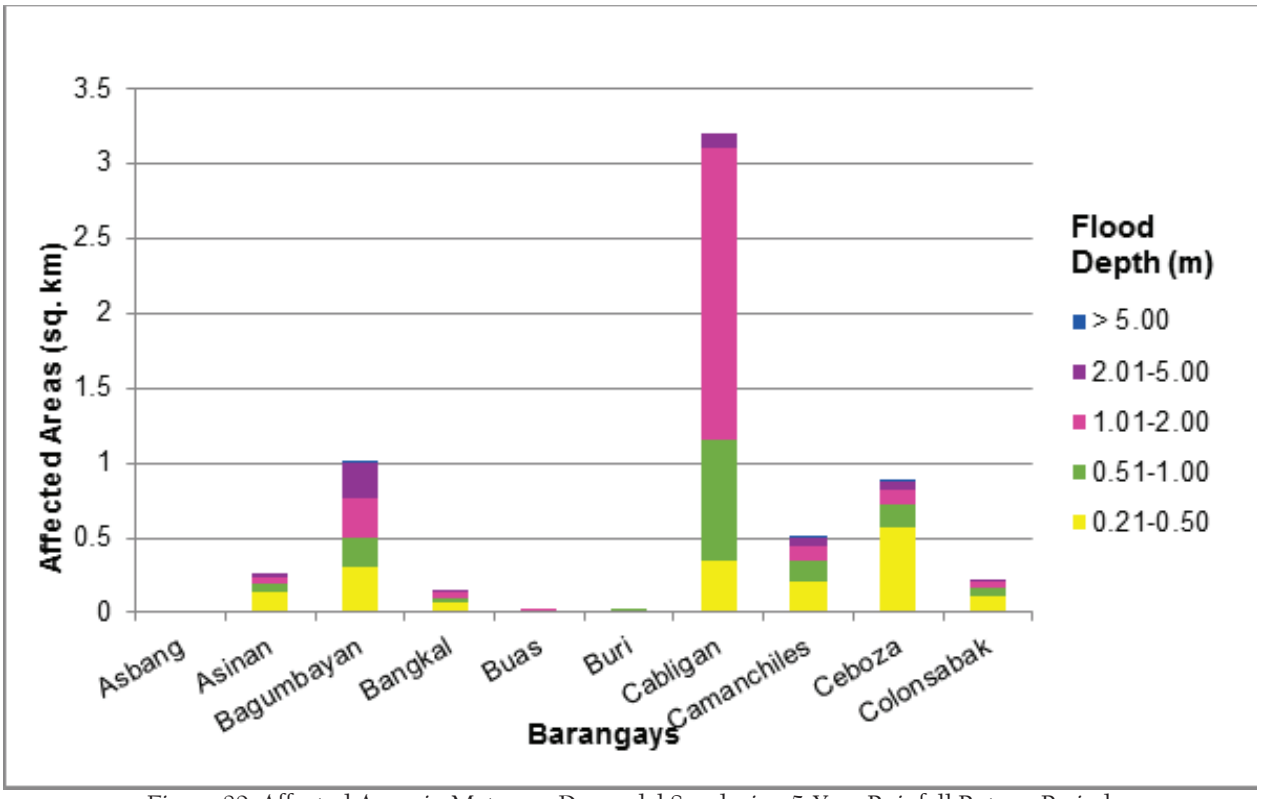


Figure 89. Affected Areas in Matanao, Davao del Sur during 5-Year Rainfall Return Period

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

DIGOS - PADADA BASIN		Affected Barangays in Matanao									
		Asbang	Asinan	Bagumbayan	Bangkal	Buas	Buri	Cabligan	Camanchiles	Ceboza	Colonsabak
Affected Area (sq. km.)	0-0.20	0.04	1.07	3.2	0.7	0.09	0.1	0.32	2.29	2.91	0.74
	0.21-0.50	0.0012	0.14	0.31	0.071	0.0099	0.0088	0.35	0.21	0.58	0.11
	0.51-1.00	0.000001	0.061	0.2	0.031	0.0009	0.0013	0.81	0.13	0.14	0.052
	1.01-2.00	0	0.039	0.26	0.032	0.0001	0	1.94	0.094	0.1	0.037
	2.01-5.00	0	0.023	0.23	0.0058	0	0	0.1	0.057	0.055	0.0022
	> 5.00	0	0	0.011	0	0	0	0	0.0013	0.011	0

DIGOS - PADADA BASIN		Affected Barangays in Matanao Z									
		Dongan-Pekong	Kabasagan	Kapok	Kibao	La Suerte	Langa-An	Lower Marber	Manga	New Katipunan	New Visayas
Affected Area (sq. km.)	0-0.20	2.78	1.14	0.5	1.06	1.98	1.42	1.27	6.08	5.77	2.51
	0.21-0.50	0.16	0.1	0.045	0.05	0.52	0.26	0.12	1.67	0.44	0.62
	0.51-1.00	0.2	0.021	0.014	0.046	0.28	0.018	0.084	2.34	0.28	0.043
	1.01-2.00	0.14	0.015	0.02	0.039	0.098	0.025	0.092	2.36	0.23	0.0013
	2.01-5.00	0.11	0	0.0024	0.023	0.13	0.01	0.11	0.38	0.17	0.0002
	> 5.00	0	0	0	0.0013	0.026	0.00009	0.0062	0.002	0.016	0

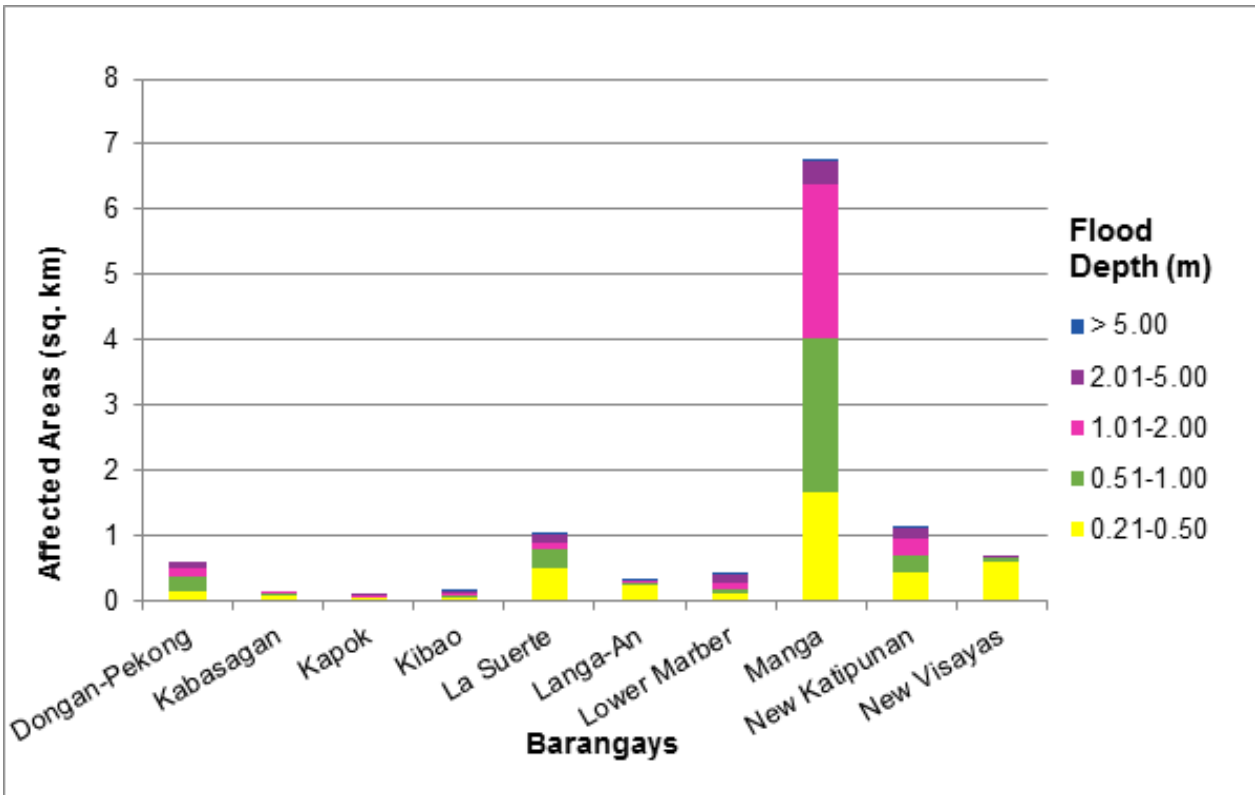


Figure 90. Affected Areas in Matanao, Davao del Sur during 5-Year Rainfall Return Period

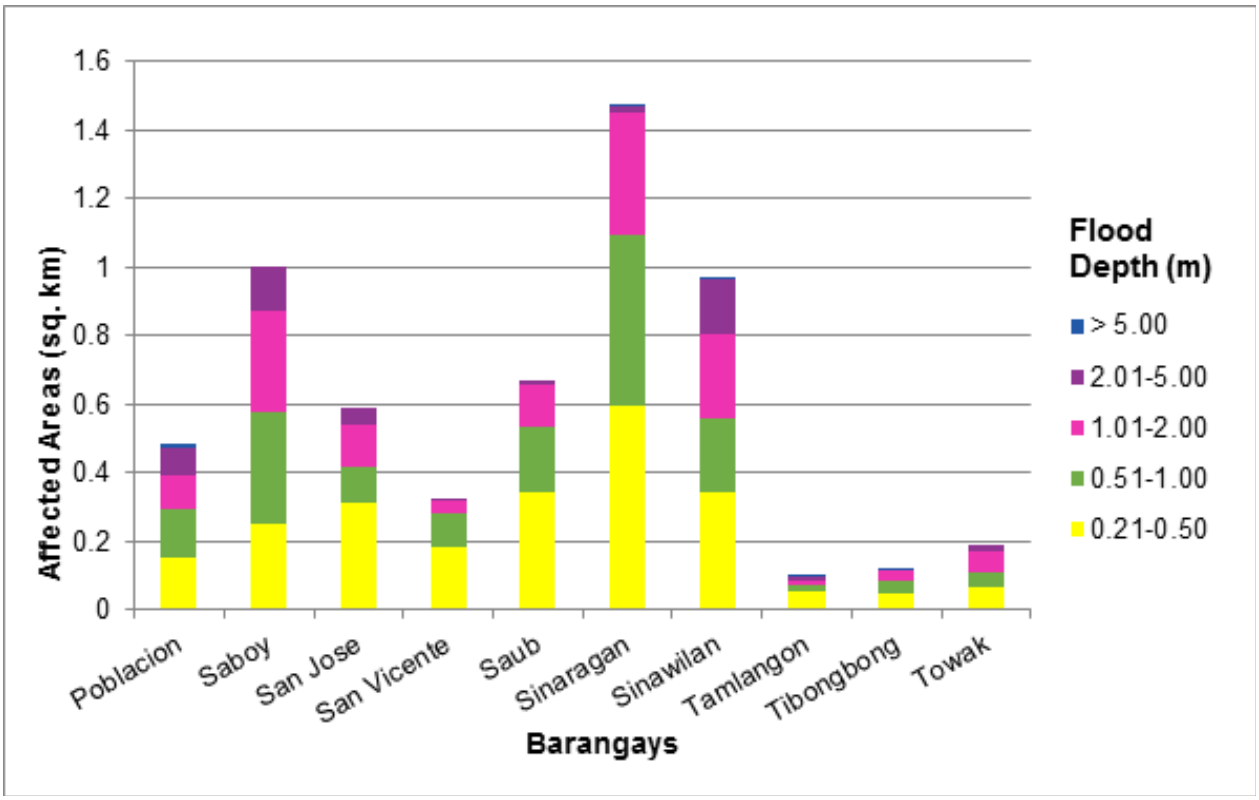


Figure 91. Affected Areas in Matanao, Davao del Sur during 5-Year Rainfall Return Period

Table 51. Affected Areas in Matanao, Davao del Sur during 5-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Matanao									
		Poblacion	**Saboy**	**San Jose**	**San Vicente**	**Saub**	**Sinaragan**	**Sinawilan**	**Tamlangon**	**Tibongbong**	**Towak**
Affected Area (sq. km.)	0-0.20	1.3	0.83	2.77	1.48	1.29	4.39	6.21	0.79	1.21	1.08
	0.21-0.50	0.15	0.25	0.31	0.19	0.34	0.6	0.35	0.052	0.048	0.068
	0.51-1.00	0.15	0.33	0.1	0.095	0.19	0.5	0.21	0.02	0.036	0.044
	1.01-2.00	0.095	0.3	0.12	0.036	0.12	0.35	0.25	0.013	0.032	0.058
	2.01-5.00	0.082	0.13	0.054	0.01	0.01	0.02	0.16	0.011	0.00089	0.018
	> 5.00	0.014	0	0	0	0	0.0014	0.0003	0.0002	0.0007	0

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

Table 52. Affected Areas in Padada, Davao del Sur during 5-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Padada								
		Almendras	Don Sergio Osmena, Sr.	Harada Butai	Lower Katipunan	Lower Limonzo	Lower Malinao	N C Ordaneza Distric	Northern Paligue	Palili
Affected Area (sq. km.)	0-0.20	0.62	1.54	3.15	4.3	1.84	3.33	0.67	2.11	5.95
	0.21-0.50	0.28	0.51	1.71	0.38	0.67	0.58	0.17	0.81	2.5
	0.51-1.00	0.034	0.37	0.53	0.15	0.15	0.33	0.043	0.19	0.58
	1.01-2.00	0	0.28	0.089	0.17	0.051	0.46	0.012	0.045	0.064
	2.01-5.00	0	0.39	0.0077	0.21	0.002	0.7	0	0.054	0.0003
	> 5.00	0	0.23	0	0.14	0	0.15	0	0.15	0

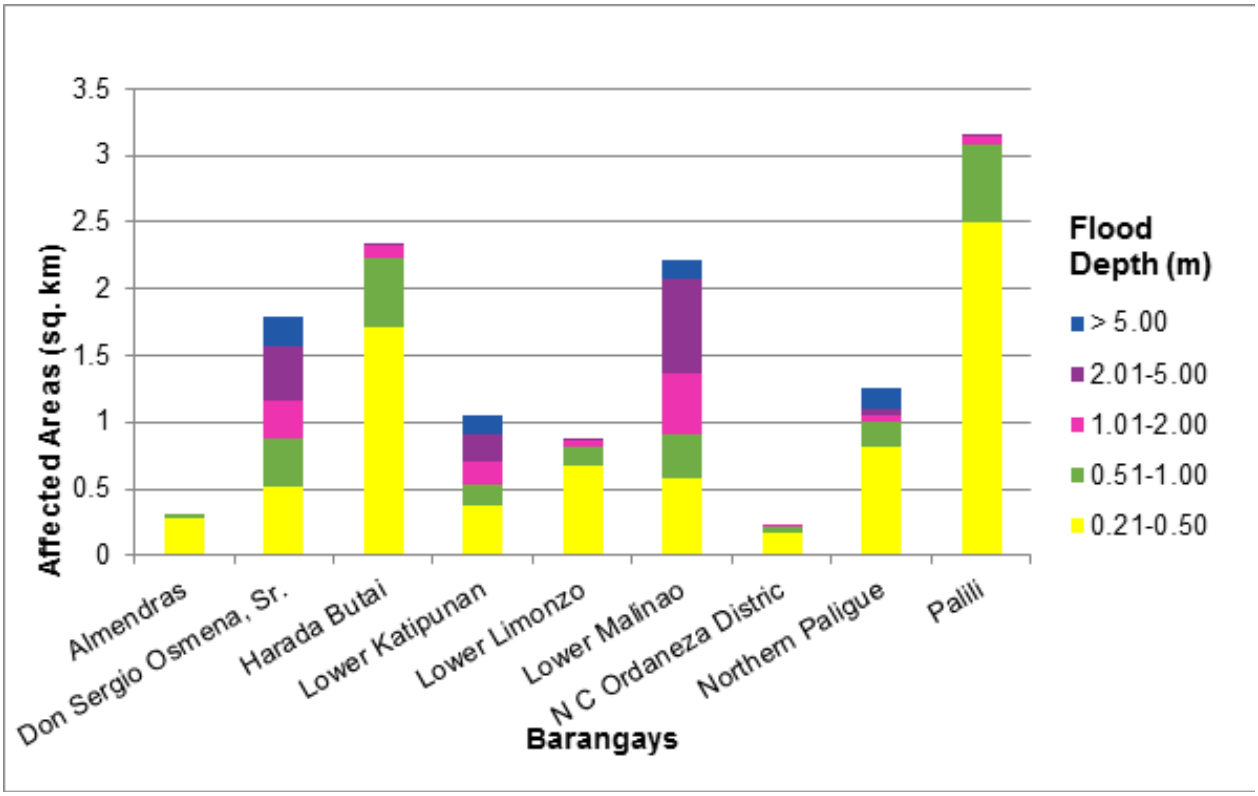


Figure 92. Affected Areas in Padada, Davao del Sur during 5-Year Rainfall Return Period

Table 53. Affected Areas in Padada, Davao del Sur during 5-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Padada							
		Piape	Punta Piape	Quirino District	San Isidro	Southern Paligue	Tulogan	Upper Limonzo	Upper Malinao
Affected Area (sq. km.)	0-0.20	0.68	2.47	0.46	1.52	1.52	1.42	2.54	2.7
	0.21-0.50	0.42	0.65	0.033	0.65	0.63	0.79	0.73	0.42
	0.51-1.00	0.15	0.23	0.0005	0.48	0.12	0.17	0.15	0.064
	1.01-2.00	0.0008	0.023	0	0.048	0.0049	0.0006	0.044	0.057
	2.01-5.00	0	0	0	0	0	0	0.0057	0.019
	> 5.00	0	0	0	0	0	0	0	0

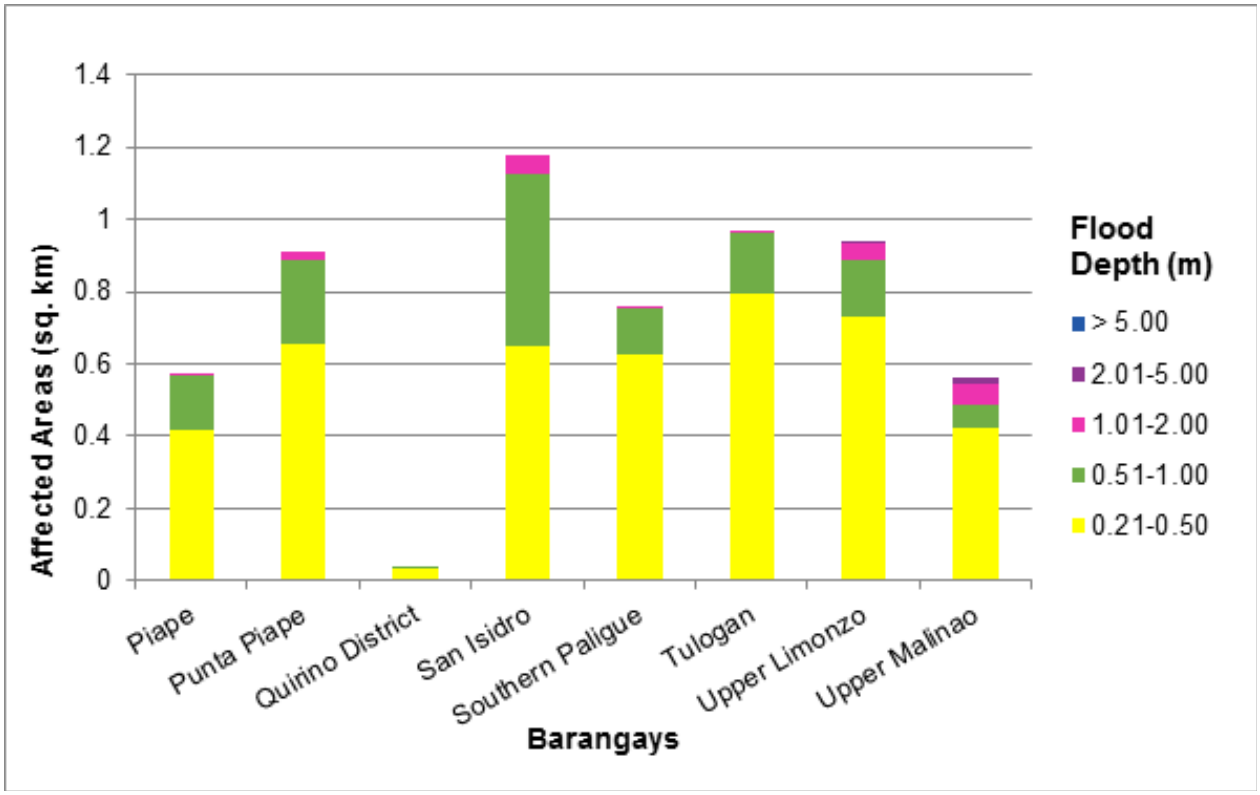


Figure 93. Affected Areas in Padada, Davao del Sur during 5-Year Rainfall Return Period

For the 5-year return period, 0.95% of the municipality of Santa Cruz with an area of 267.54 sq. km. will experience flood levels of less than 0.20 meters. 0.15% of the area will experience flood levels of 0.21 to 0.50 meters while 0.15%, 0.08%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 54. Affected Areas in Sta. Cruz, Davao del Sur during 5-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Sulop	
		Bato	Tagabuli
Affected Area (sq. km.)	0-0.20	2.48	0.068
	0.21-0.50	0.38	0.012
	0.51-1.00	0.41	0.00077
	1.01-2.00	0.21	0
	2.01-5.00	0.021	0
	> 5.00	0	0

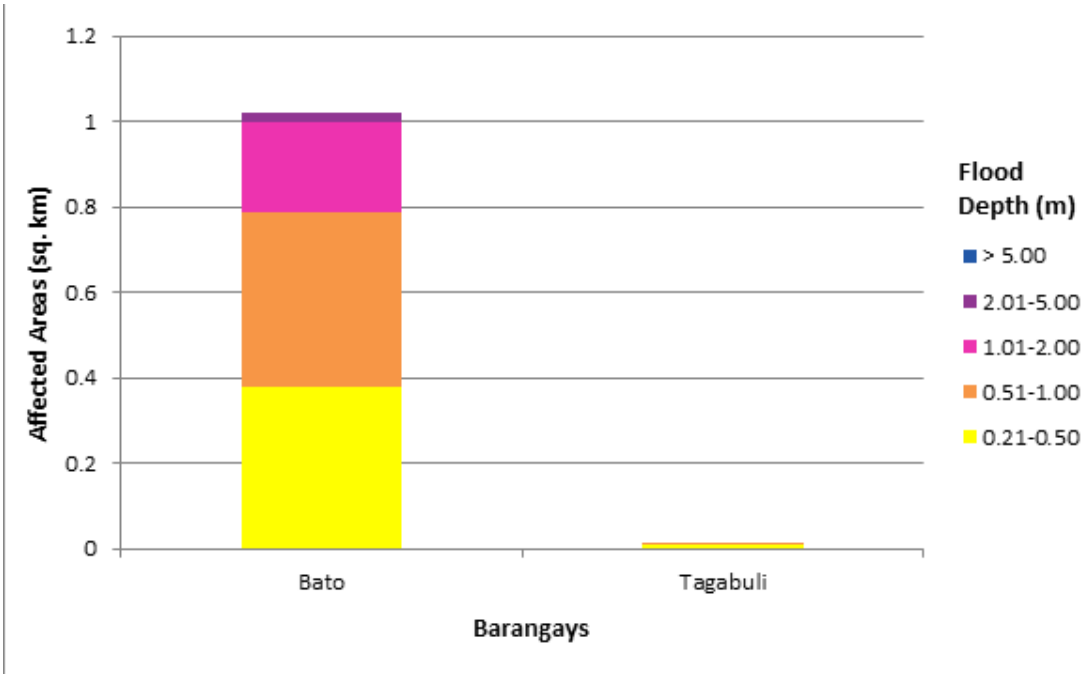


Figure 94. Affected Areas in Sta. Cruz, Davao del Sur during 5-Year Rainfall Return Period

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

Table 55. Affected Areas in Sulop, Davao del Sur during 5-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Sulop							
		Lapla	Litos	Luparan	Mckinley	New Cebu	Osmeña	Palili	Parame
Affected Area (sq. km.)	0-0.20	0.70	0.67	0.34	0.80	1.81	0.35	4.76	0.509
	0.21-0.50	0.022	0.026	0.0085	0.038	0.46	0.0105	2.19	0.013
	0.51-1.00	0.0105	0.023	0.0045	0.062	0.27	0.0054	0.803	0.011
	1.01-2.00	0.014	0.013	0.0057	0.050	0.067	0.0025	0.96	0.0097
	2.01-5.00	0.019	0.014	0.0093	0.00609	0.0096	0.0012	0.0051	0.0106
	> 5.00	0.0042	0.0104	0.0014	0	0.0004	0	0	0.0003

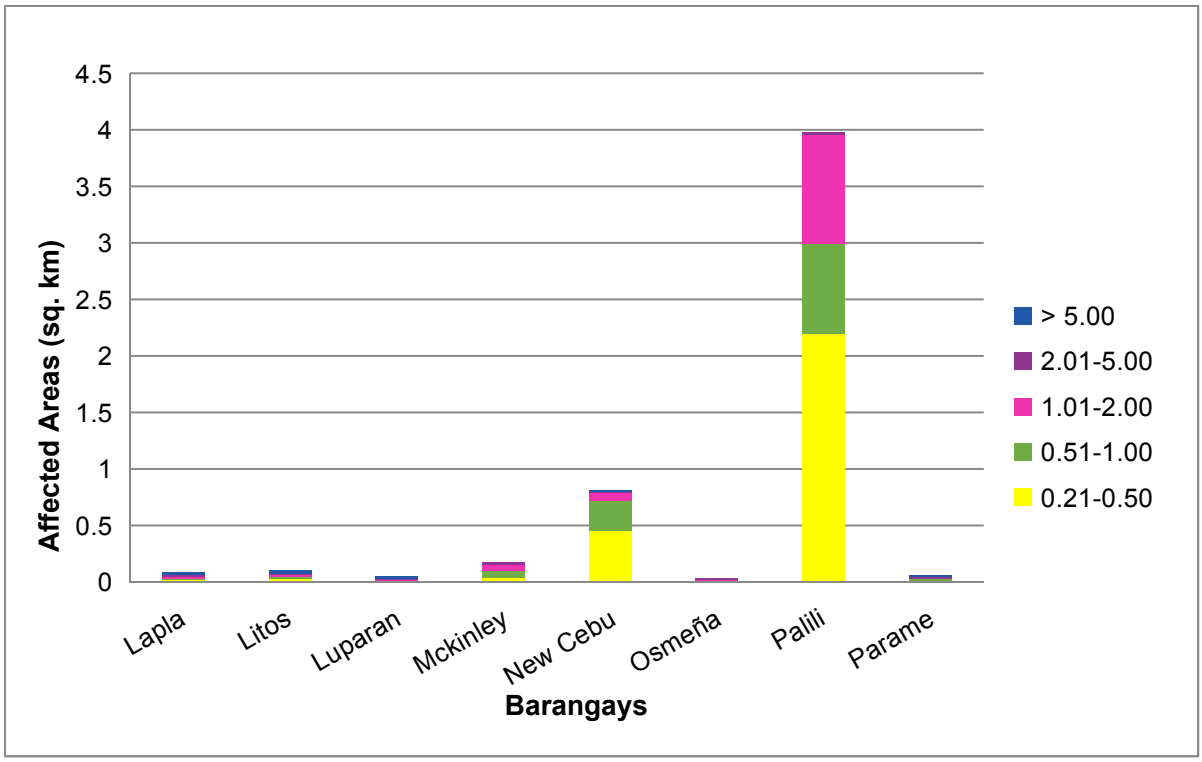


Figure 95. Affected Areas in Sulop, Davao del Sur during 5-Year Rainfall Return Period

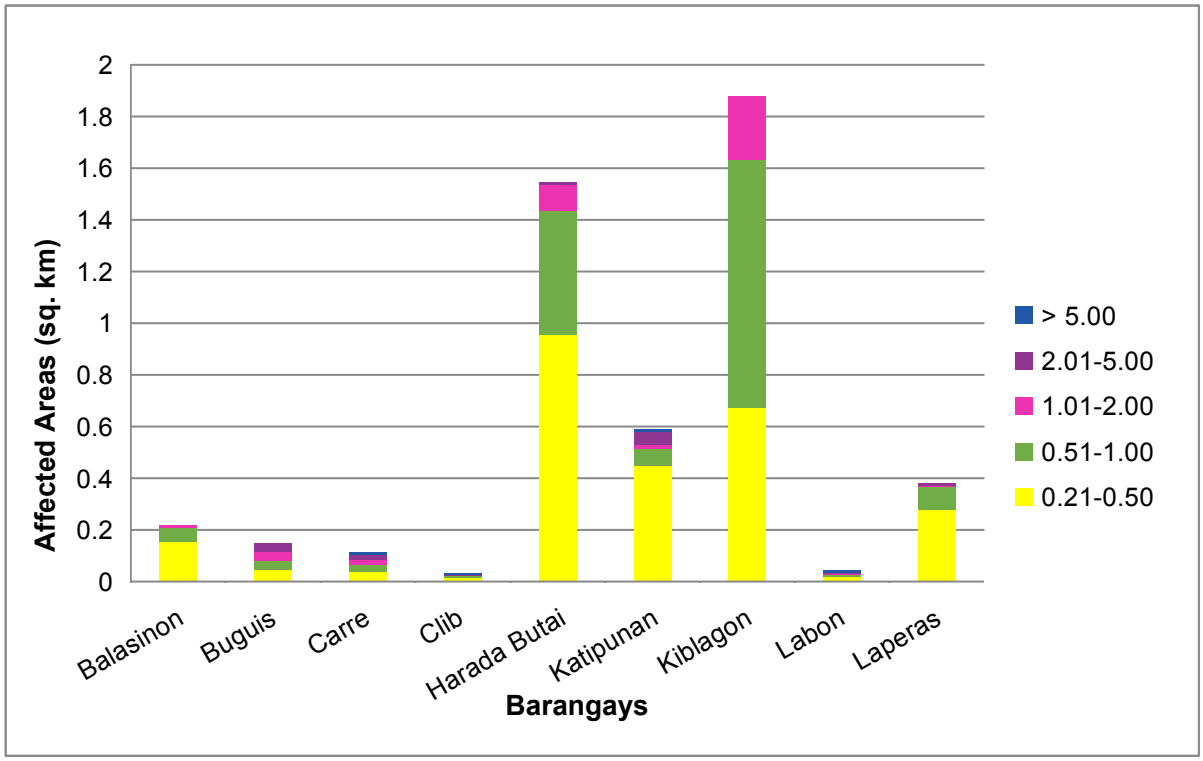


Figure 96. Affected Areas in Sulop, Davao del Sur during 5-Year Rainfall Return Period

Table 56. Affected Areas in Sulop, Davao del Sur during 5-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Sulop								
		Balasinon	Buguis	Carre	Clib	Harada Butai	Katipunan	Kiblagon	Labon	Laperas
Affected Area (sq. km.)	0-0.20	0.23	1.19	0.9	0.52	2.1	1.18	0.43	0.48	0.83
	0.21-0.50	0.15	0.046	0.04	0.015	0.95	0.45	0.67	0.018	0.28
	0.51-1.00	0.055	0.033	0.024	0.0078	0.48	0.067	0.96	0.0081	0.091
	1.01-2.00	0.00074	0.035	0.021	0.0017	0.099	0.016	0.25	0.0054	0.0025
	2.01-5.00	0	0.034	0.017	0.0012	0.0028	0.047	0	0.0048	0.0006
	> 5.00	0	0	0.0036	0.00014	0	0.011	0	0.0014	0

Table 57. Affected Areas in Sulop, Davao del Sur during 5-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Sulop							
		Poblacion	Roxas	Solongvale	Tagolilong	Tala-O	Talas	Tanwalang	Waterfall
Affected Area (sq. km.)	0-0.20	0.502	3.22	2.302	1.039	2.55	1.12	1.77	0.901
	0.21-0.50	0.58	0.17	1.13	0.028	0.77	0.84	0.65	0.492
	0.51-1.00	0.68	0.18	0.46	0.011	0.37	0.59	0.27	0.30
	1.01-2.00	0.702	0.12	0.092	0.011	0.11	0.17	0.060	0.022
	2.01-5.00	0.0007	0.0502	0.0005	0.0056	0.0001	0.0004	0.24	0.00099
	> 5.00	0	0.016	0	0.0005	0	0	0.12	0

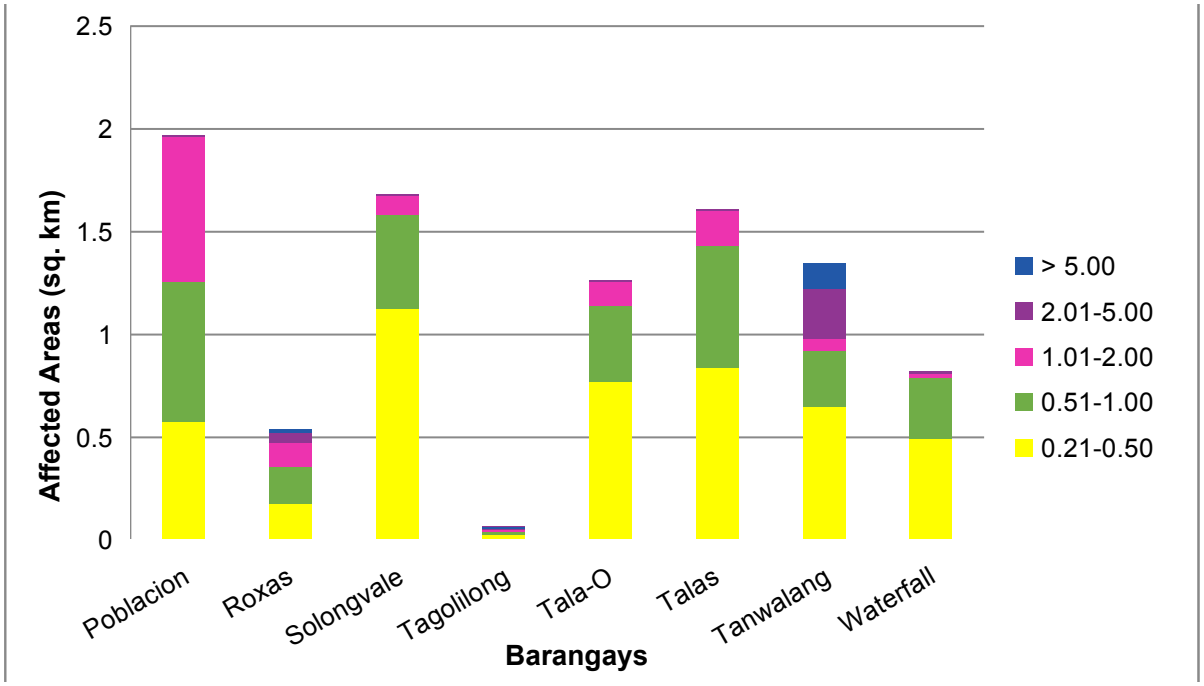


Figure 97. Affected Areas in Sulop, Davao del Sur during 5-Year Rainfall Return Period

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

Table 56. Affected Areas in Columbio, Sultan Kudarat during 5-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangay in Columbio
		Datablao
Affected Area (sq. km.)	0-0.20	1.39067
	0.21-0.50	0.02969
	0.51-1.00	0.014751
	1.01-2.00	0.01476
	2.01-5.00	0.017973
	> 5.00	0.0043

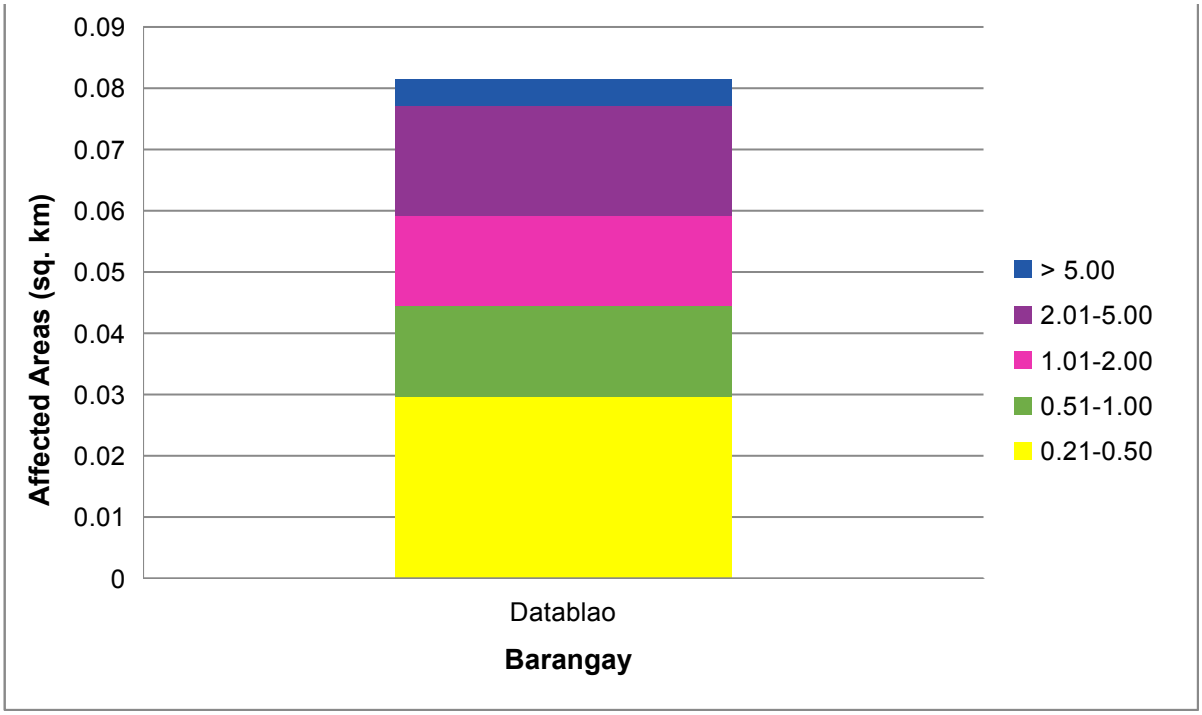


Figure 98. Affected Areas in Columbio, Sultan Kudarat during 5-Year Rainfall Return Period

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

Table 58. Affected Areas in Bansalan, Davao del Sur during 5-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Bansalan							
		Anonang	Bonifacio	Buenavista	Mabunga	New Clarin	Poblacion	Poblacion Dos	Union
Affected Area (sq. km.)	0-0.20	1.61	1.34	2.07	3.34	0.53	1.29	1.27	3.01
	0.21-0.50	0.14	0.15	0.31	1.81	0.055	0.19	0.53	0.34
	0.51-1.00	0.085	0.054	0.18	0.28	0.057	0.15	0.18	0.34
	1.01-2.00	0.036	0.027	0.065	0.16	0.055	0.07	0.036	0.2
	2.01-5.00	0.013	0.014	0.03	0.048	0.011	0.07	0.0006	0.07
	> 5.00	0	0.0002	0.0001	0.0001	0	0.0057	0	0.0049

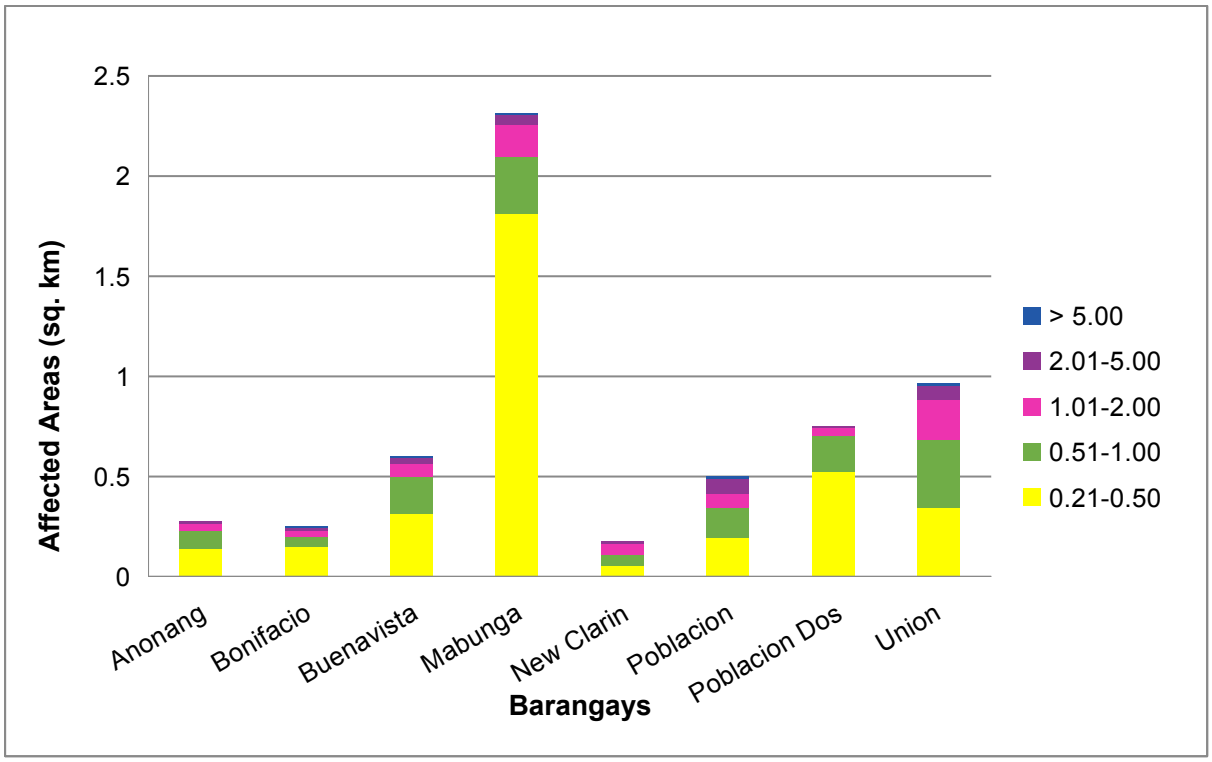


Figure 99. Affected Areas in Bansalan, Davao del Sur during 25-Year Rainfall Return Period

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

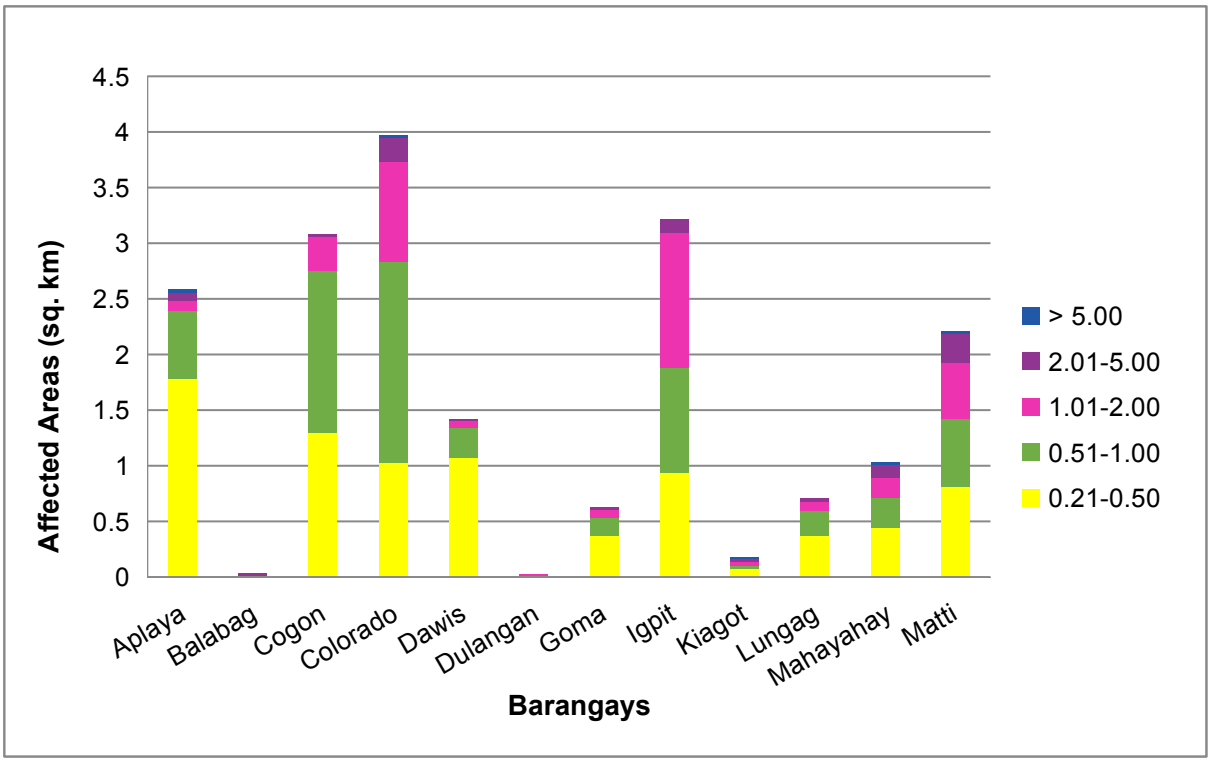


Figure 100. Affected Areas in Digos City, Davao del Sur during 25-Year Rainfall Return Period

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

DIGOS - PADADA BASIN		Affected Barangays in Digos City											
		Aplaya	Balabag	Cogon	Colorado	Dawis	Dulangan	Goma	Igpit	Kiagot	Lungag	Mahayahay	Matti
Affected Area (sq. km.)	0-0.20	2.12	0.17	2.08	3.78	1.66	0.098	2.49	1.18	1.92	4.69	4.35	4.7
	0.21-0.50	1.78	0.0071	1.3	1.02	1.07	0.0079	0.37	0.94	0.071	0.37	0.44	0.81
	0.51-1.00	0.62	0.0044	1.46	1.82	0.27	0.00037	0.17	0.95	0.031	0.22	0.27	0.6
	1.01-2.00	0.085	0.0039	0.3	0.89	0.057	0.000015	0.066	1.2	0.036	0.085	0.18	0.51
	2.01-5.00	0.071	0.0027	0.0075	0.22	0.018	0	0.026	0.12	0.025	0.03	0.12	0.25
	> 5.00	0.015	0	0	0.0027	0	0	0	0	0.00078	0	0.0046	0.0068

DIGOS - PADADA BASIN		Affected Barangays in Digos City											
		Ruparan	San Agustin	San Jose	San Miguel	San Roque	Sinawilan	Soong	Tiguman	Tres de Mayo	Zone 1	Zone 2	Zone 3
Affected Area (sq. km.)	0-0.20	3.03	4.07	1.31	0.71	5.04	3.39	0.79	1.13	2.04	2.12	0.84	1.67
	0.21-0.50	0.18	0.79	1.04	1.06	0.67	0.49	0.031	0.93	0.46	0.071	0.35	0.94
	0.51-1.00	0.081	0.33	0.29	0.69	0.46	0.43	0.012	0.55	0.46	0.047	0.16	0.14
	1.01-2.00	0.053	0.15	0.28	0.3	0.19	0.09	0.008	0.077	0.21	0.03	0.049	0.012
	2.01-5.00	0.047	0.075	0.0034	0	0.056	0.037	0.0061	0.00063	0.16	0.044	0.092	0.0067
	> 5.00	0.0041	0	0	0	0	0.0099	0	0	0.056	0.0057	0.14	0.01

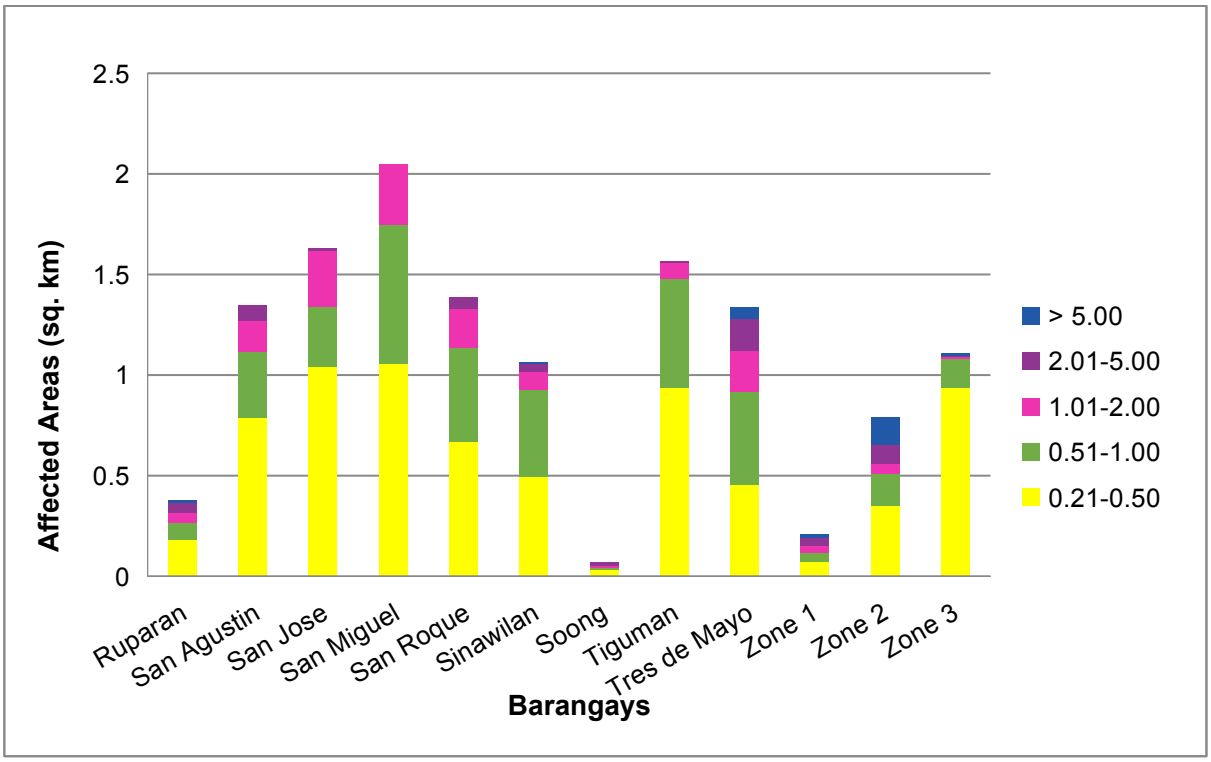


Figure 101. Affected Areas in Digos City, Davao del Sur during 25-Year Rainfall Return Period

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

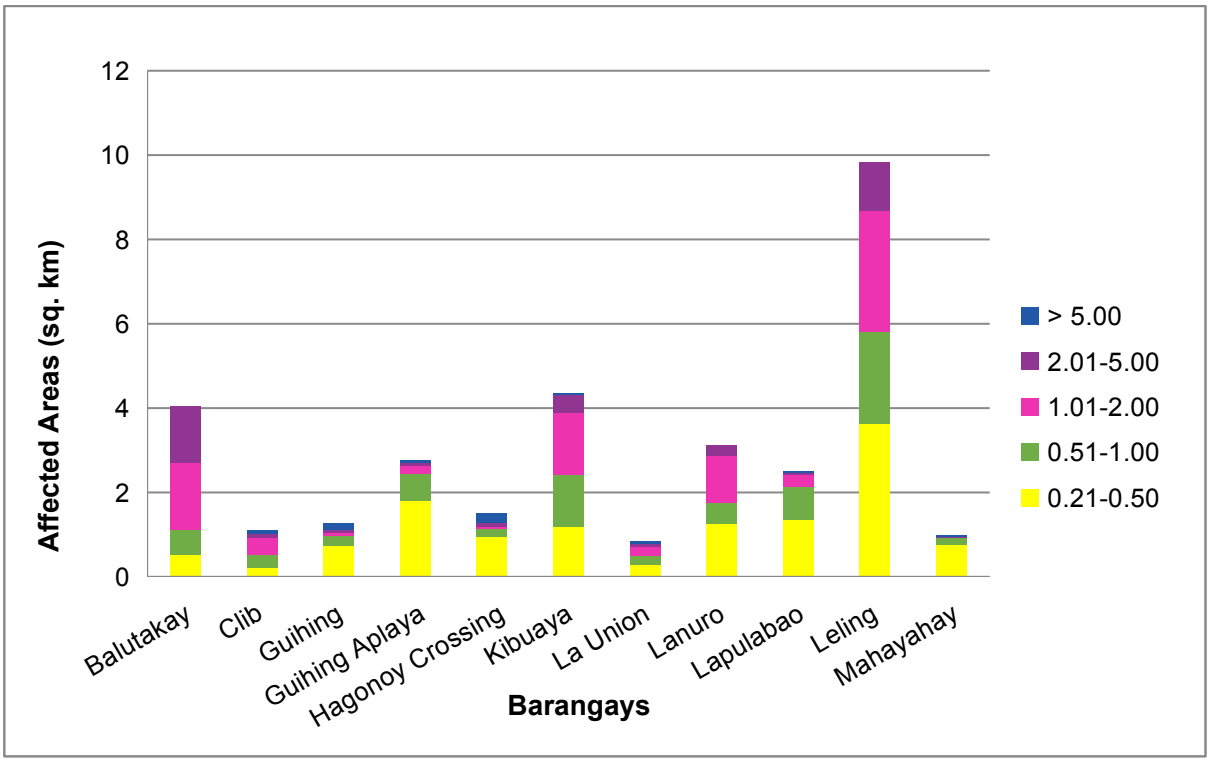


Figure 102. Affected Areas in Hagonoy, Davao del Sur during 25-Year Rainfall Return Period

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

DIGOS - PADADA BASIN		Affected Barangays in Hagonoy										
		Balutakay	Clib	Guihing	Guihing Aplaya	Hagonoy Crossing	Kibuaya	La Union	Lanuro	Lapulabao	Leling	Mahayahay
Affected Area (sq. km.)	0-0.20	0.48	2.4	1.23	2.6	1.4	1.72	3.03	1.04	2.63	3.95	1.52
	0.21-0.50	0.52	0.2	0.75	1.8	0.94	1.19	0.29	1.27	1.35	3.64	0.75
	0.51-1.00	0.61	0.32	0.24	0.64	0.21	1.23	0.21	0.49	0.77	2.17	0.16
	1.01-2.00	1.58	0.42	0.054	0.19	0.058	1.48	0.23	1.11	0.31	2.88	0.021
	2.01-5.00	1.33	0.096	0.078	0.084	0.097	0.41	0.072	0.24	0.028	1.15	0.013
	> 5.00	0	0.029	0.16	0.017	0.21	0.0013	0.012	0	0.0029	0	0.0012

DIGOS - PADADA BASIN		Affected Barangays in Hagonoy									
		Malabang Damsite	Maliit Digos	New Quezon	Paligue	Poblacion	Sacub	San Guillermo	San Isidro	Sinayawan	Tologan
Affected Area (sq. km.)	0-0.20	2.3	1.44	2.56	0.52	2.07	2.74	0.71	0.023	0.8	0.75
	0.21-0.50	0.26	0.38	0.47	0.53	1.36	3.2	0.11	0.053	0.89	0.36
	0.51-1.00	0.29	0.71	0.25	0.24	0.21	1.09	0.25	0.33	0.66	0.13
	1.01-2.00	0.16	0.36	0.29	0.041	0.079	0.0052	0.5	1.5	0.82	0.051
	2.01-5.00	0.061	0.063	1.42	0.0001	0.051	0	0.16	0.61	0	0.093
	> 5.00	0.0013	0.0004	0.0001	0	0.021	0	0.015	0	0	0.13

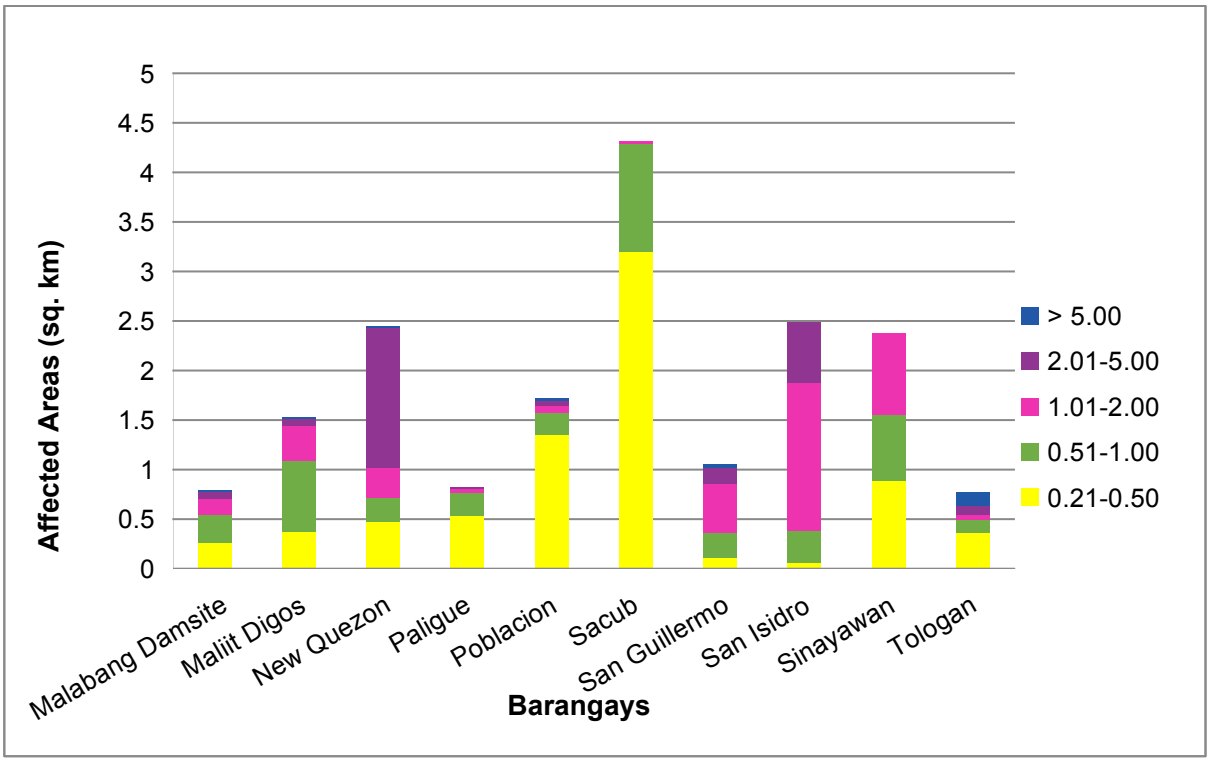


Figure 103. Affected Areas in Hagonoy, Davao del Sur during 25-Year Rainfall Return Period

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

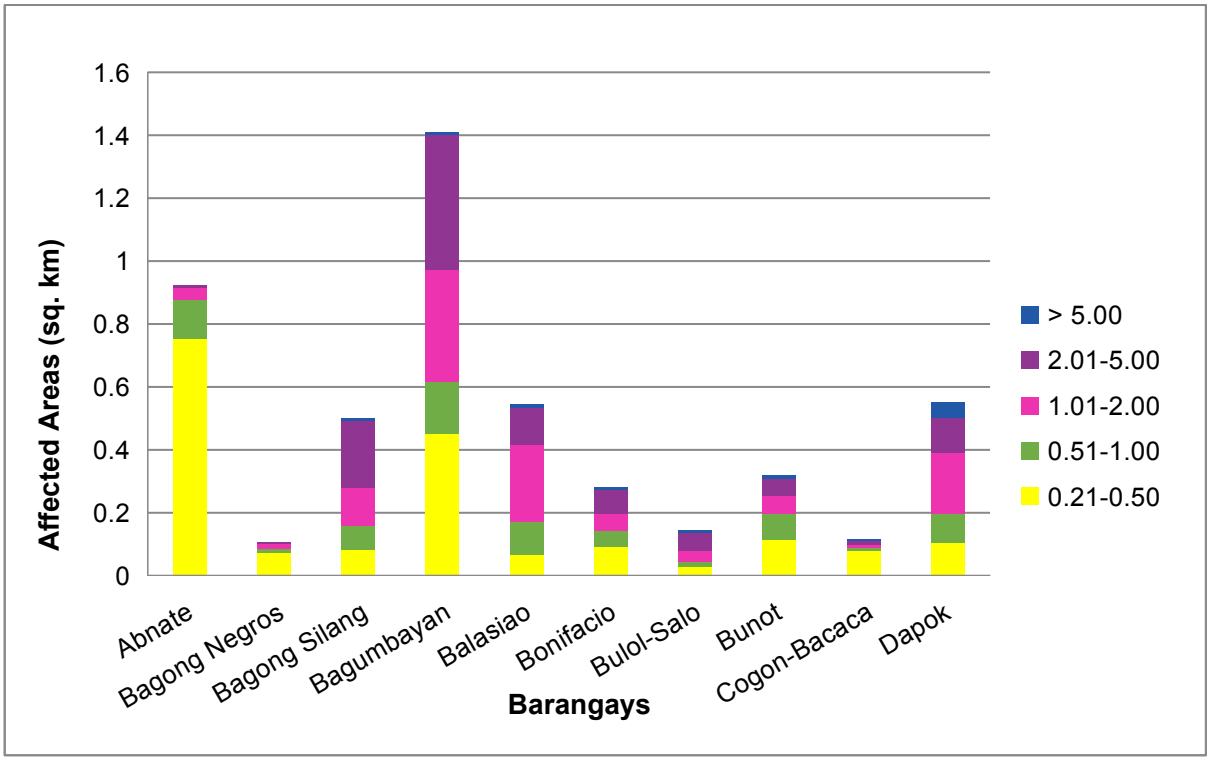


Figure 104. Affected Areas in Kiblawan, Davao del Sur during 25-Year Rainfall Return Period

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

DIGOS - PADADA BASIN		Affected Barangays in Kiblawan									
		Abnate	Bagong Negros	Bagong Silang	Bagumbayan	Balasiao	Bonifacio	Bulol-Salo	Bunot	Cogon-Bacaca	Dapok
Affected Area (sq. km.)	0-0.20	2.46	1.23	1.3	4.66	1.64	2.26	0.87	2.64	0.53	1.64
	0.21-0.50	0.75	0.074	0.081	0.45	0.067	0.093	0.027	0.11	0.08	0.11
	0.51-1.00	0.12	0.012	0.076	0.16	0.1	0.05	0.017	0.085	0.0092	0.09
	1.01-2.00	0.038	0.014	0.12	0.36	0.25	0.055	0.034	0.058	0.01	0.2
	2.01-5.00	0.0012	0.0062	0.21	0.43	0.12	0.077	0.058	0.052	0.011	0.11
	> 5.00	0	0	0.0081	0.0015	0.0037	0.0074	0.0036	0.012	0.0001	0.049

DIGOS - PADADA BASIN		Affected Barangays in Kiblawan									
		Ihan	Kibongbong	Kimlawis	Kisulan	Lati-An	Manual	Maraga-A	Molopolo	New Sibonga	Panaglib
Affected Area (sq. km.)	0-0.20	0.39	0.64	1.39	0.86	1.16	1.03	1.44	2.35	1.45	0.46
	0.21-0.50	0.063	0.23	0.026	0.053	0.044	0.68	0.047	0.17	0.085	0.038
	0.51-1.00	0.085	0.019	0.016	0.013	0.051	0.035	0.029	0.062	0.11	0.04
	1.01-2.00	0.12	0.015	0.025	0.011	0.13	0	0.055	0.13	0.28	0.074
	2.01-5.00	0.11	0.021	0.039	0.0057	0.17	0	0.052	0.14	0.45	0.39
	> 5.00	0.039	0.00049	0.0065	0	0.067	0	0.0009	0.006	0.028	0.18

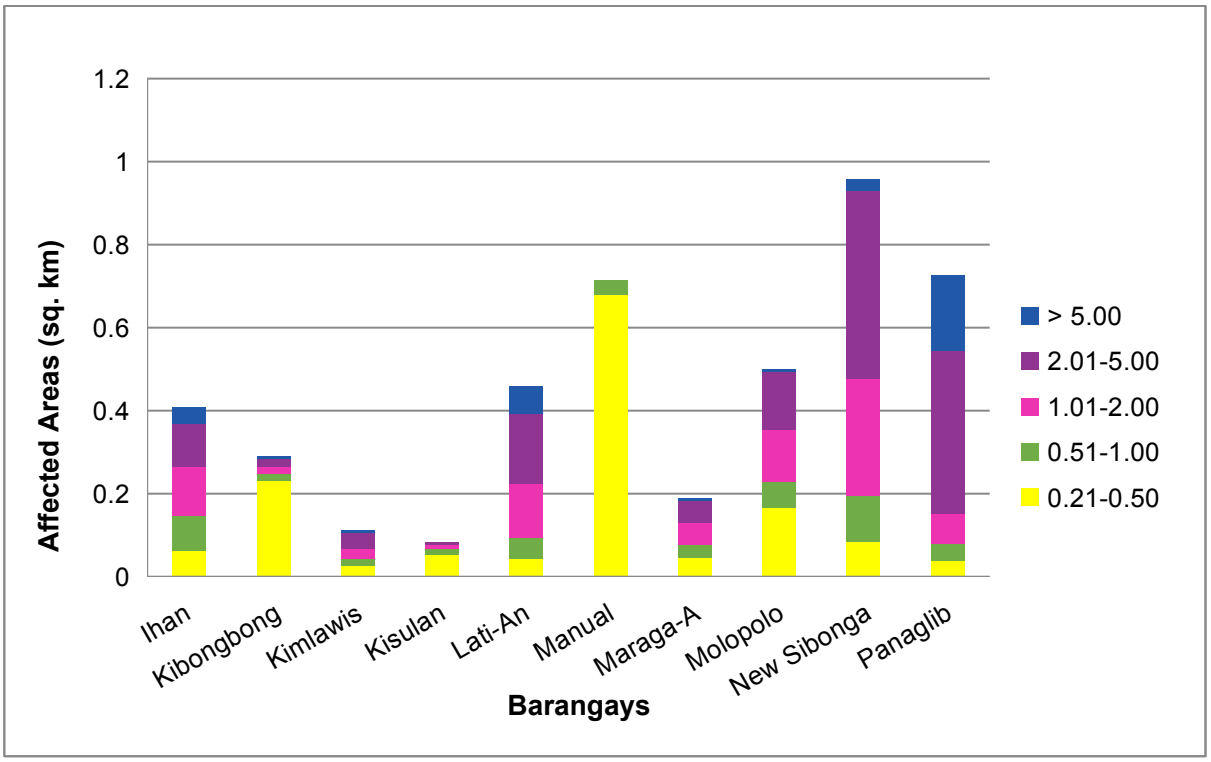


Figure 105. Affected Areas in Kiblawan, Davao del Sur during 25-Year Rainfall Return Period

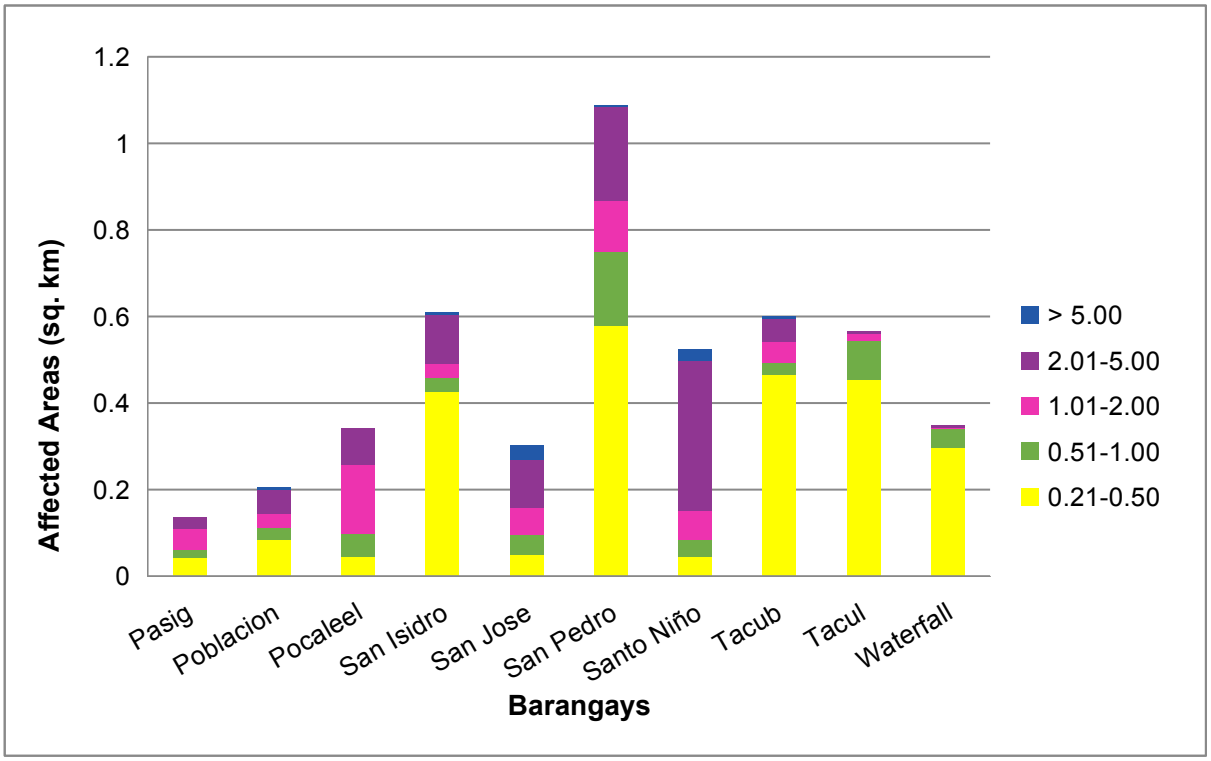


Figure 106. Affected Areas in Kiblawan, Davao del Sur during 25-Year Rainfall Return Period

Table 62. Affected Areas in Kiblawan, Davao del Sur during 25-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Kiblawan									
		Pasig	**Poblacion**	**Pocaleel**	**San Isidro**	**San Jose**	**San Pedro**	**Santo Niño**	**Tacub**	**Tacul**	**Waterfall**
Affected Area (sq. km.)	0-0.20	0.57	1.66	1.17	1.1	0.76	3.07	1.09	1.22	0.72	0.56
	0.21-0.50	0.042	0.083	0.046	0.43	0.05	0.58	0.046	0.46	0.45	0.3
	0.51-1.00	0.019	0.029	0.052	0.032	0.045	0.17	0.038	0.029	0.091	0.043
	1.01-2.00	0.047	0.031	0.16	0.032	0.062	0.12	0.068	0.047	0.016	0.0024
	2.01-5.00	0.027	0.057	0.084	0.11	0.11	0.22	0.35	0.055	0.00093	0.00091
	> 5.00	0	0.0047	0	0.0015	0.034	0.0003	0.026	0.0022	0	0

For the 25-year return period, 0.30% of the municipality of Magsaysay with an area of 109.8 sq. km. will experience flood levels of less than 0.20 meters. 0.05% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, 0.01%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 63. Affected Areas in Magsaysay, Davao del Sur during 25-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangay in Magsaysay
		New Ilocos
Affected Area (sq. km.)	0-0.20	0.33
	0.21-0.50	0.059
	0.51-1.00	0.021
	1.01-2.00	0.016
	2.01-5.00	0.0057
	> 5.00	0

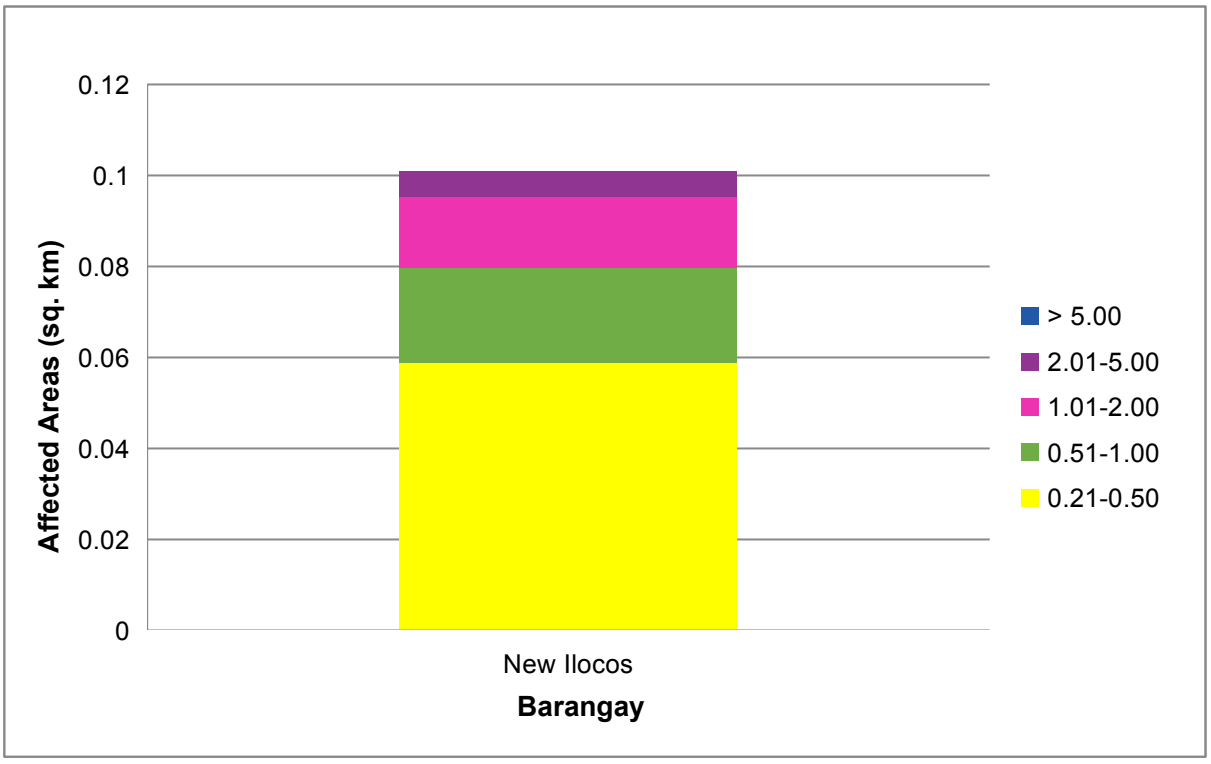


Figure 107. Affected Areas in Magsaysay, Davao del Sur during 25-Year Rainfall Return Period

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

Table 64. Affected Areas in Malalag, Davao del Sur during 25-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Malalag					
		Bagumbayan	Bolton	Kiblagon	Lapu-Lapu	Mabini	New Baclayon
Affected Area (sq. km.)	0-0.20	0.014	0.53	11.83	30.05	1.36	2.22
	0.21-0.50	0.006	0.1	3.45	1.73	0.04	0.56
	0.51-1.00	0.008	0.037	3.59	1.19	0.02	0.67
	1.01-2.00	0.0033	0.018	2.19	1.68	0.013	0.68
	2.01-5.00	0	0.012	0.41	1.95	0.015	0.032
	> 5.00	0	0.0009	0.025	0.23	0.007	0

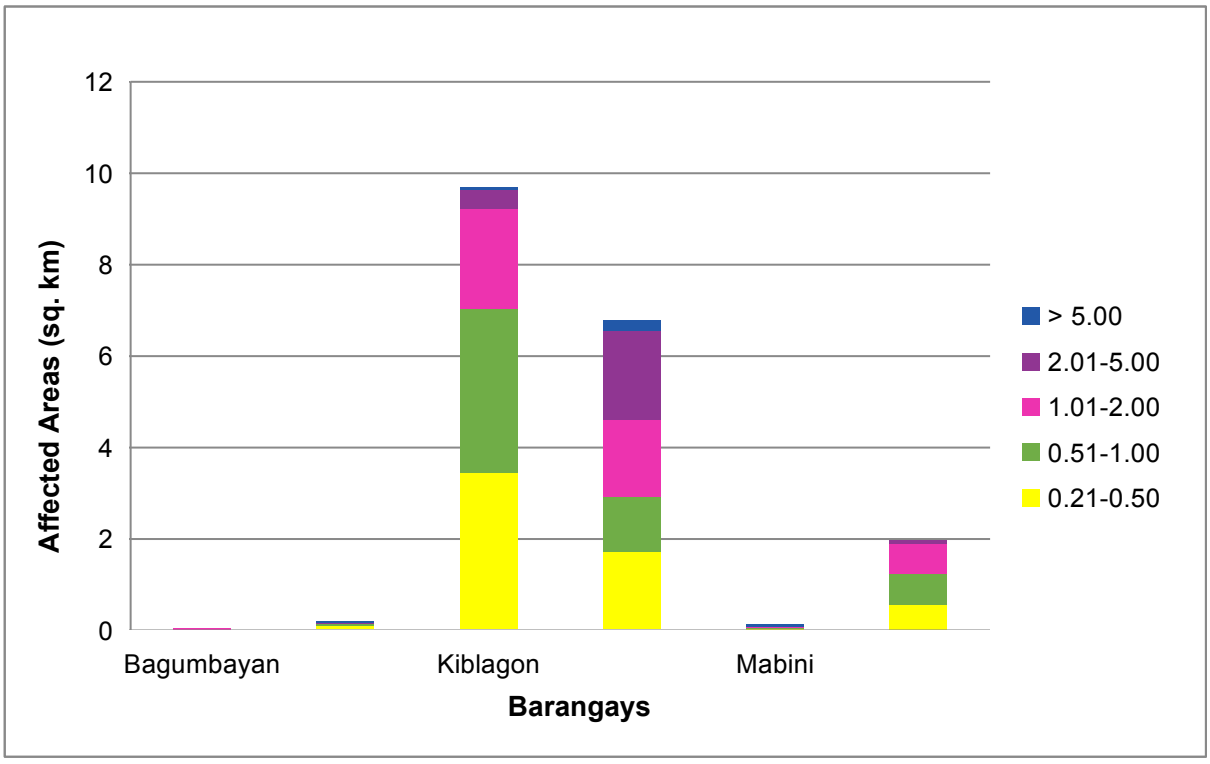


Figure 108. Affected Areas in Malalag, Davao del Sur during 25-Year Rainfall Return Period

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

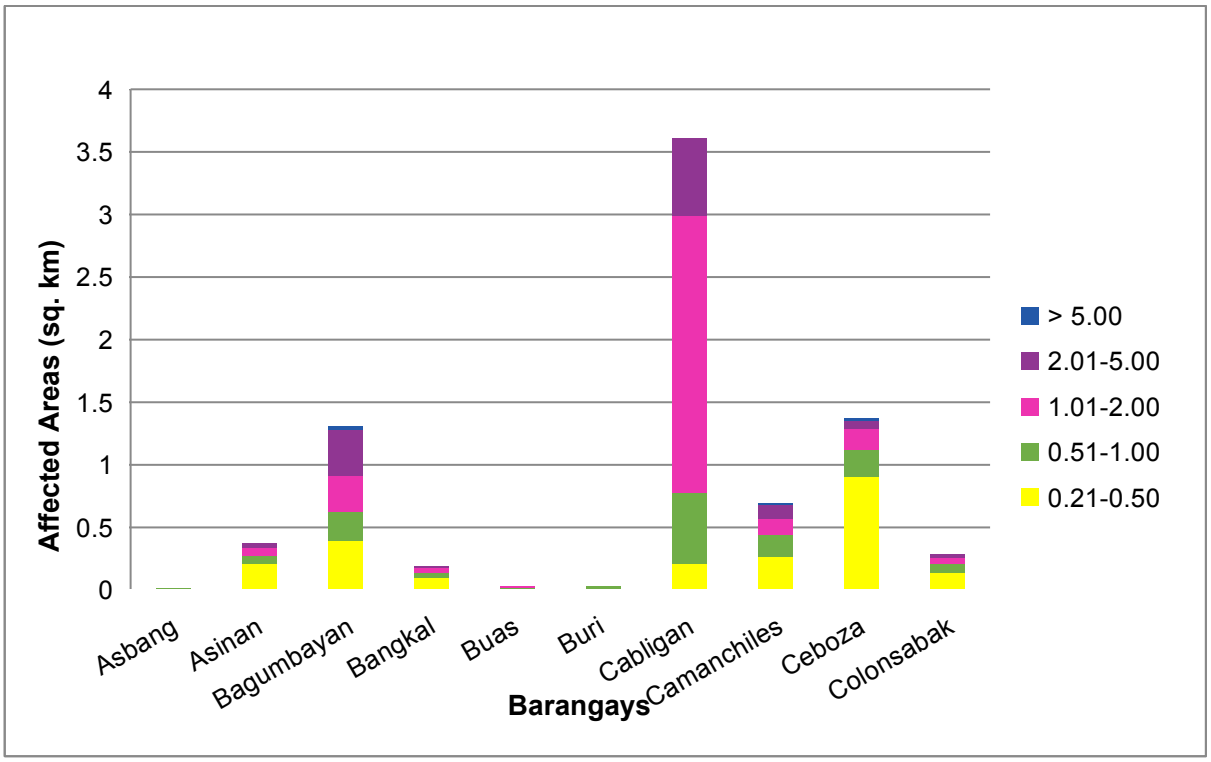


Figure 109. Affected Areas in Matanao, Davao del Sur during 25-Year Rainfall Return Period

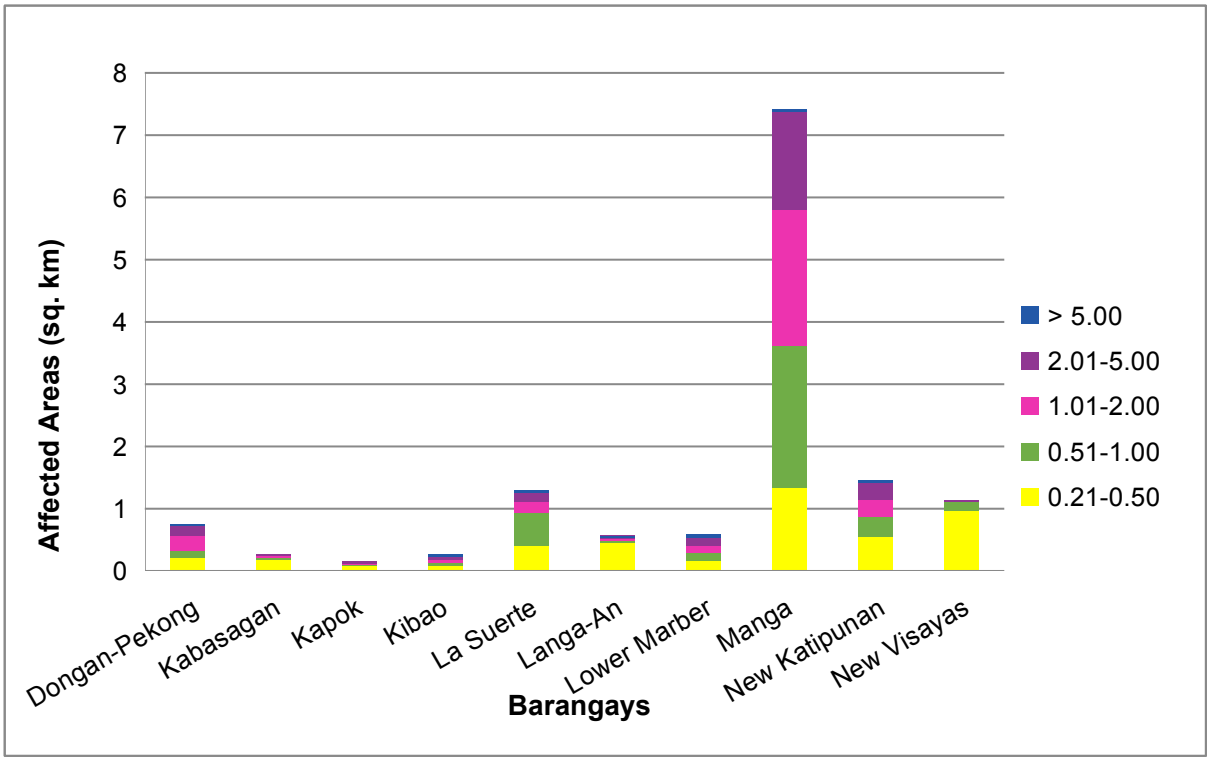


Figure 110. Affected Areas in Matanao, Davao del Sur during 25-Year Rainfall Return Period

Table 65. Affected Areas in Matanao, Davao del Sur during 25-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Matanao									
		Asbang	Asinan	Bagumbayan	Bangkal	Buas	Buri	Cabligan	Camanchiles	Ceboza	Colonsabak
Affected Area (sq. km.)	0-0.20	0.039	0.96	2.9	0.65	0.085	0.1	0.084	2.15	2.43	0.68
	0.21-0.50	0.0017	0.21	0.4	0.096	0.014	0.01	0.21	0.27	0.9	0.14
	0.51-1.00	0.00015	0.06	0.23	0.042	0.002	0.0028	0.57	0.18	0.22	0.07
	1.01-2.00	0	0.062	0.29	0.04	0.00061	0	2.21	0.12	0.17	0.049
	2.01-5.00	0	0.033	0.37	0.016	0	0	0.62	0.11	0.062	0.0092
	> 5.00	0	0	0.032	0	0	0	0	0.016	0.018	0

DIGOS - PADADA BASIN		Affected Barangays in Matanao									
		Dongan-Pekong	Kabasagan	Kapok	Kibao	La Suerte	Langa-An	Lower Marber	Manga	New Katipunan	New Visayas
Affected Area (sq. km.)	0-0.20	2.68	1.04	0.45	1.03	1.74	1.19	1.12	5.53	5.45	2.06
	0.21-0.50	0.21	0.19	0.084	0.086	0.4	0.46	0.17	1.33	0.55	0.97
	0.51-1.00	0.12	0.025	0.016	0.045	0.54	0.034	0.13	2.28	0.32	0.14
	1.01-2.00	0.24	0.024	0.022	0.056	0.17	0.024	0.11	2.2	0.28	0.0022
	2.01-5.00	0.15	0.0015	0.01	0.039	0.14	0.022	0.14	1.57	0.27	0.0004
	> 5.00	0.00065	0	0	0.0027	0.041	0.00046	0.021	0.0045	0.038	0

Table 66. Affected Areas in Matanao, Davao del Sur during 25-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Matanao									
		Poblacion	**Saboy**	**San Jose**	**San Vicente**	**Saub**	**Sinaragan**	**Sinawilan**	**Tamlangon**	**Tibongbong**	**Towak**
Affected Area (sq. km.)	0-0.20	1.19	0.69	2.5	1.4	1.11	4.08	5.97	0.74	1.19	1.03
	0.21-0.50	0.14	0.21	0.49	0.21	0.37	0.62	0.39	0.083	0.06	0.091
	0.51-1.00	0.14	0.24	0.13	0.15	0.26	0.57	0.26	0.028	0.038	0.045
	1.01-2.00	0.18	0.46	0.13	0.066	0.17	0.51	0.25	0.018	0.044	0.056
	2.01-5.00	0.12	0.23	0.12	0.02	0.042	0.077	0.31	0.013	0.0035	0.044
	> 5.00	0.022	0.00045	0.000021	0	0	0.0024	0.0092	0.0024	0.0009	0

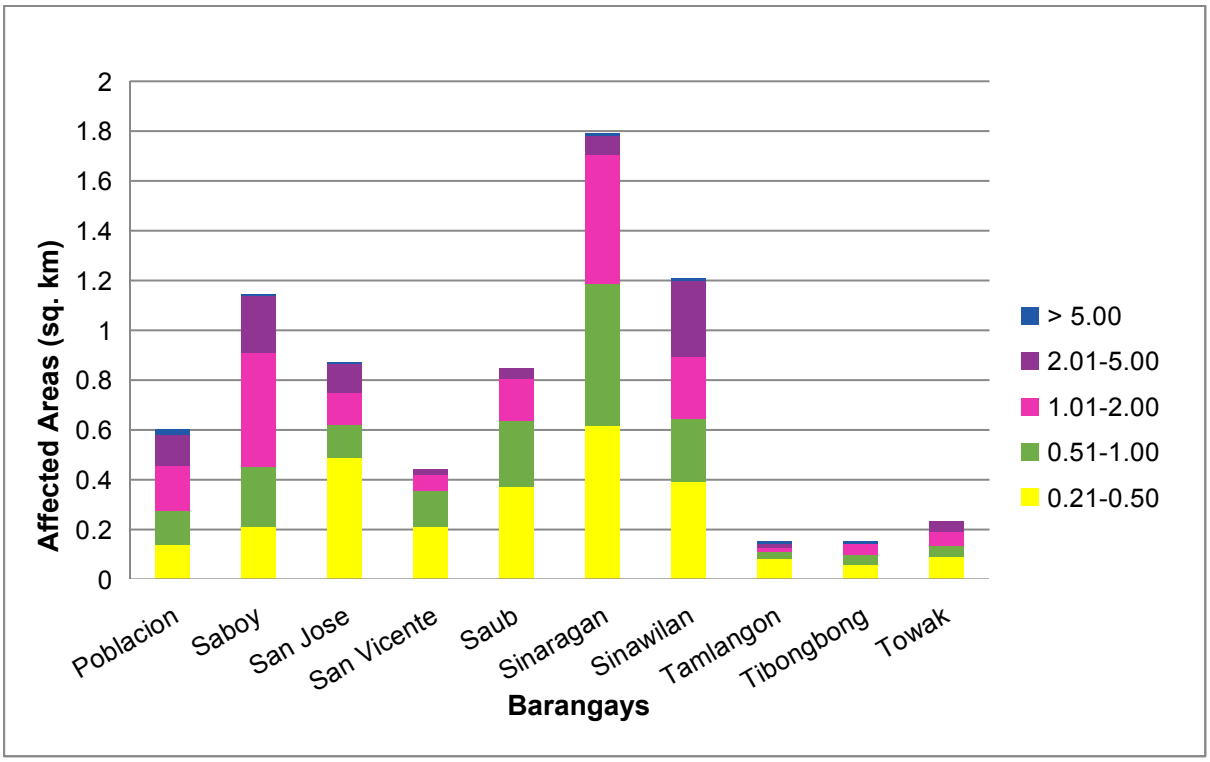


Figure 111. Affected Areas in Matanao, Davao del Sur during 25-Year Rainfall Return Period

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

Table 67. Affected Areas in Padada, Davao del Sur during 25-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Padada								
		Almendras	Don Sergio Osmena, Sr.	Harada Butai	Lower Katipunan	Lower Limonzo	Lower Malinao	N C Ordaneza Distric	Northern Paligue	Palili
Affected Area (sq. km.)	0-0.20	0.46	1.22	2.3	4	1.24	2.89	0.59	1.58	4.58
	0.21-0.50	0.4	0.4	1.95	0.51	1.13	0.63	0.23	1.11	3.19
	0.51-1.00	0.085	0.45	0.96	0.24	0.27	0.39	0.063	0.37	1.17
	1.01-2.00	0.0003	0.55	0.26	0.17	0.067	0.45	0.018	0.065	0.15
	2.01-5.00	0	0.22	0.014	0.28	0.003	0.87	0.0001	0.046	0.0016
	> 5.00	0	0.51	0	0.15	0	0.33	0	0.19	0

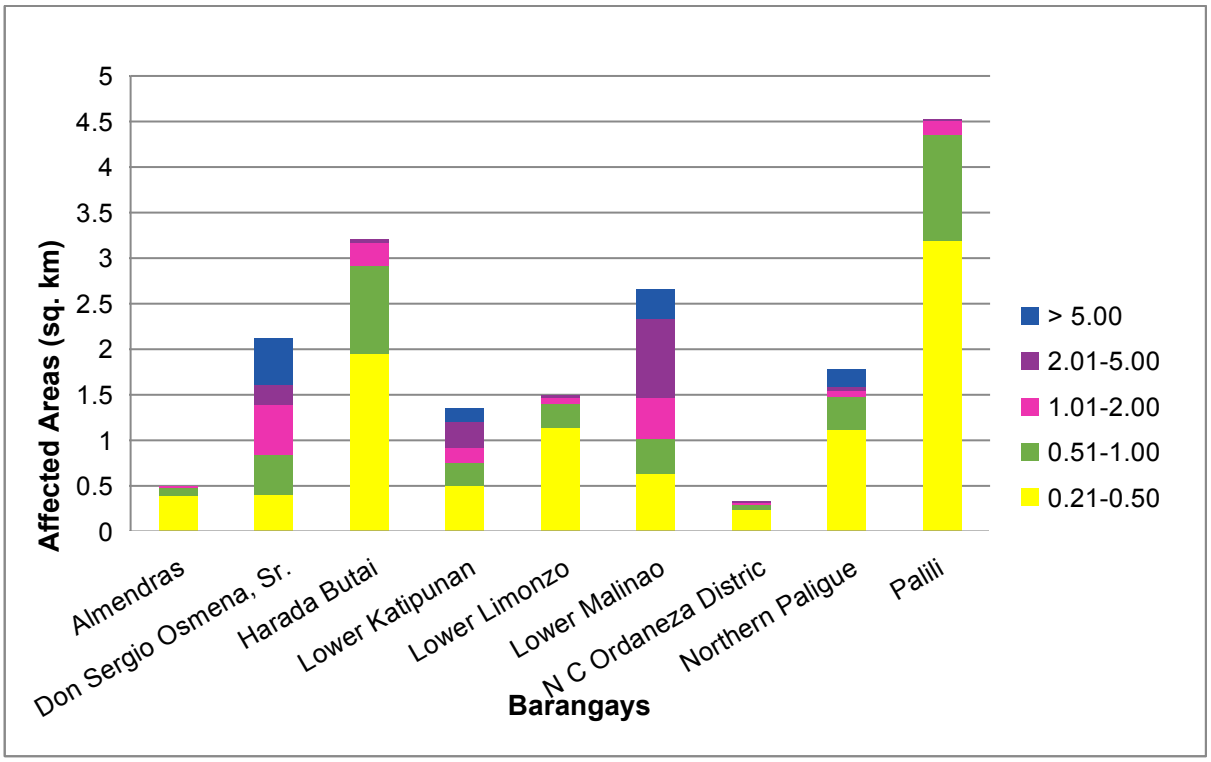


Figure 112. Affected Areas in Padada, Davao del Sur during 25-Year Rainfall Return Period

Table 68. Affected Areas in Padada, Davao del Sur during 25-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Padada							
		Piape	Punta Piape	Quirino District	San Isidro	Southern Paligue	Tulogan	Upper Limonzo	Upper Malinao
Affected Area (sq. km.)	0-0.20	0.49	2.02	0.45	1.2	1.19	0.98	1.98	2.36
	0.21-0.50	0.35	0.9	0.04	0.61	0.83	1.05	1.15	0.71
	0.51-1.00	0.38	0.41	0.0048	0.64	0.25	0.34	0.27	0.085
	1.01-2.00	0.02	0.05	0	0.24	0.012	0.012	0.073	0.067
	2.01-5.00	0	0	0	0.013	0	0	0.0085	0.039
	> 5.00	0	0	0	0	0	0	0	0

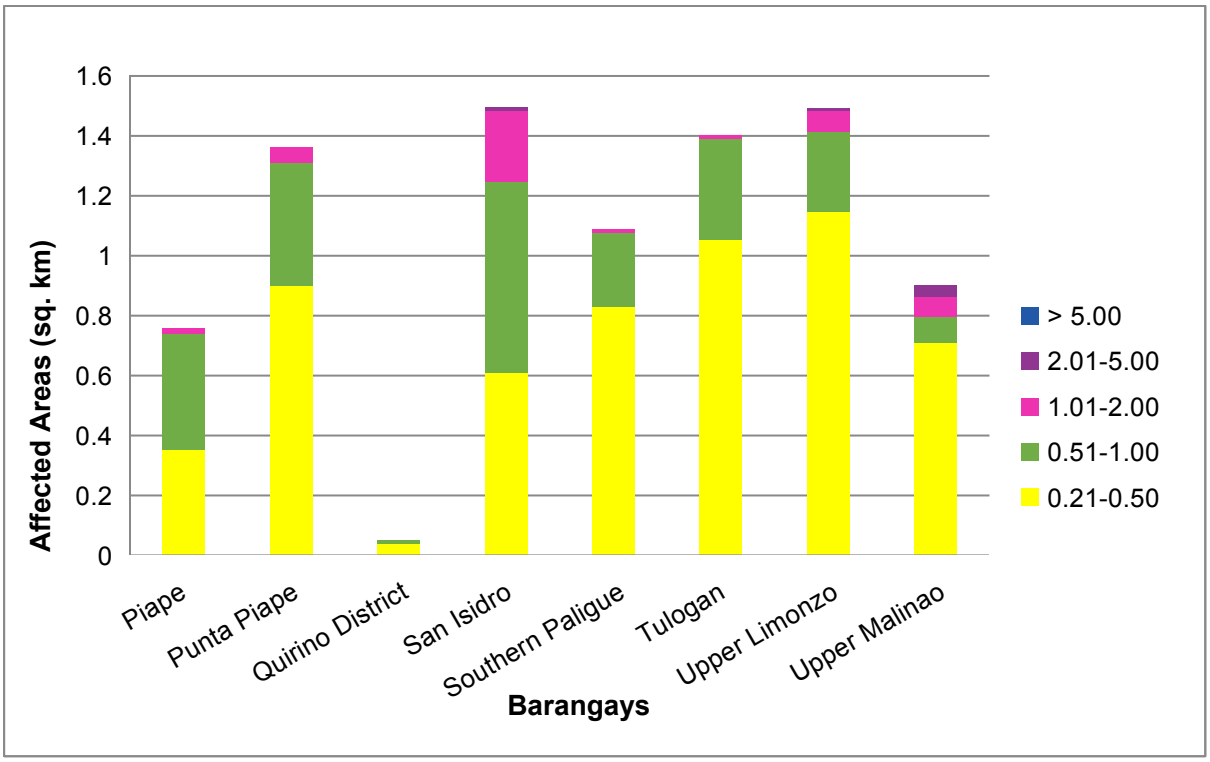


Figure 113.. Affected Areas in Padada, Davao del Sur during 25-Year Rainfall Return Period

For the 25-year return period, 0.86% of the municipality of Santa Cruz with an area of 267.54 sq. km. will experience flood levels of less than 0.20 meters. 0.13% of the area will experience flood levels of 0.21 to 0.50 meters while 0.14%, 0.19%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 69. Affected Areas in Santa Cruz, Davao del Sur during 25-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Santa Cruz	
		Bato	Tagabuli
Affected Area (sq. km.)	0-0.20	2.25	0.055
	0.21-0.50	0.32	0.015
	0.51-1.00	0.35	0.01
	1.01-2.00	0.51	0.0001
	2.01-5.00	0.065	0
	> 5.00	0.0033	0

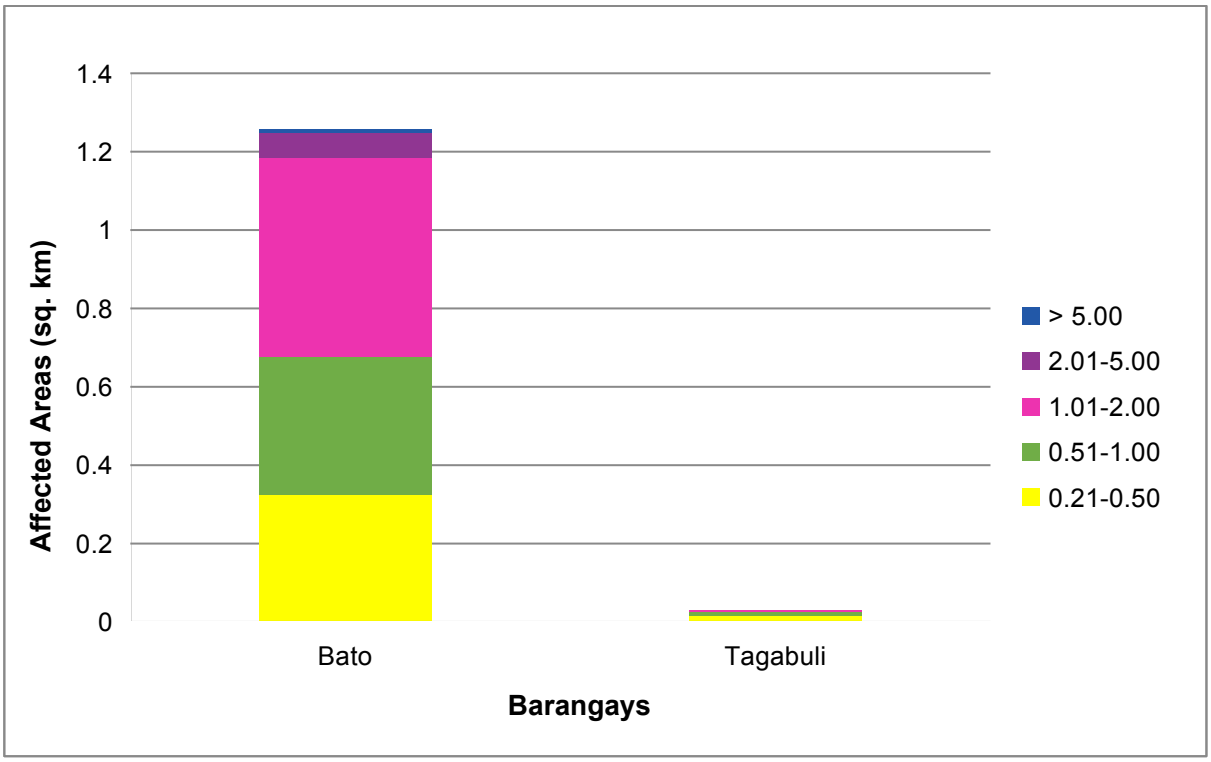


Figure 114. Affected Areas in Santa Cruz, Davao del Sur during 25-Year Rainfall Return Period

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

Table 70. Affected Areas in Sulop, Davao del Sur during 25-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Sulop								
		Balasinon	Buguis	Carre	Clib	Harada Butai	Katipunan	Kiblagon	Labon	Laperas
Affected Area (sq. km.)	0-0.20	0.18	1.16	0.88	0.51	1.53	0.93	0.21	0.47	0.77
	0.21-0.50	0.15	0.047	0.043	0.018	1.09	0.6	0.43	0.022	0.25
	0.51-1.00	0.11	0.032	0.031	0.01	0.8	0.15	0.94	0.01	0.18
	1.01-2.00	0.0037	0.037	0.025	0.003	0.21	0.02	0.67	0.0071	0.0084
	2.01-5.00	0	0.06	0.023	0.0015	0.0082	0.049	0.057	0.0053	0.00045
	> 5.00	0	0.0013	0.0055	0.00054	0	0.013	0	0.0021	0.00015

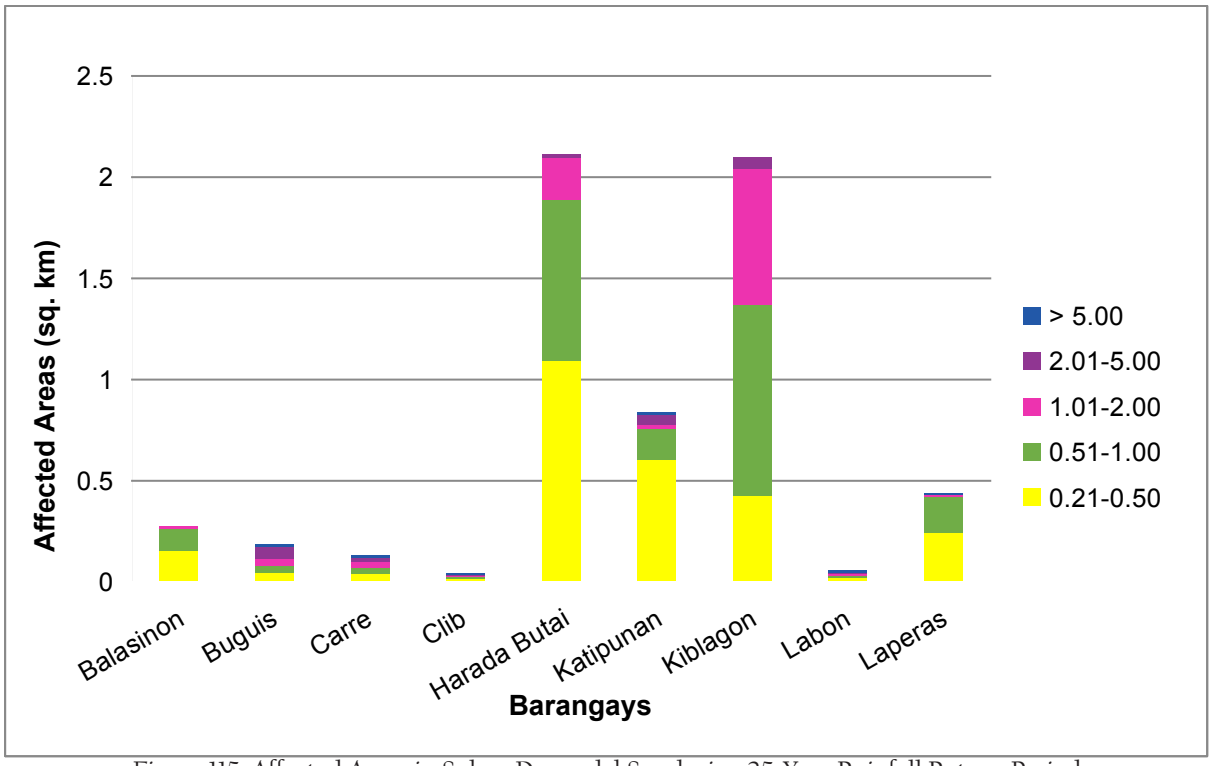


Figure 115. Affected Areas in Sulop, Davao del Sur during 25-Year Rainfall Return Period

Table 71. Affected Areas in Sulop, Davao del Sur during 25-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Sulop							
		Lapla	Litos	Luparan	Mckinley	New Cebu	Osmeña	Palili	Parame
Affected Area (sq. km.)	0-0.20	0.68	0.65	0.33	0.77	1.7	0.35	3.4	0.5
	0.21-0.50	0.025	0.023	0.011	0.037	0.32	0.013	2.87	0.014
	0.51-1.00	0.013	0.024	0.0055	0.042	0.47	0.0064	1.02	0.012
	1.01-2.00	0.014	0.024	0.0052	0.084	0.083	0.0033	1.17	0.011
	2.01-5.00	0.022	0.017	0.011	0.019	0.035	0.0014	0.27	0.015
	> 5.00	0.009	0.013	0.0036	0	0.0013	0	0	0.0003

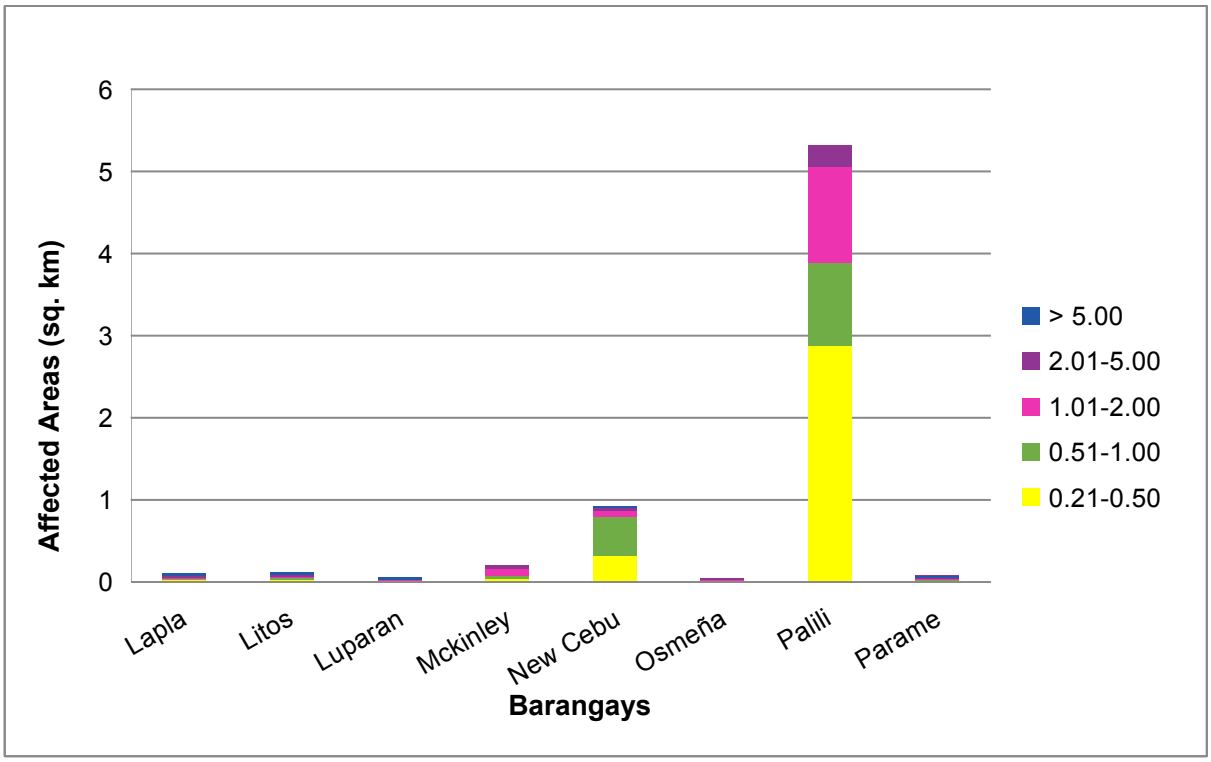


Figure 116. Affected Areas in Sulop, Davao del Sur during 25-Year Rainfall Return Period

Table 72. Affected Areas in Sulop, Davao del Sur during 25-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Sulop							
		Poblacion	Roxas	Solongvale	Tagolilong	Tala-O	Talas	Tanwalang	Waterfall
Affected Area (sq. km.)	0-0.20	0.28	3.1	1.94	1.02	2.07	0.73	1.45	0.76
	0.21-0.50	0.36	0.16	0.97	0.036	0.98	0.75	0.63	0.45
	0.51-1.00	0.63	0.14	0.87	0.016	0.51	0.84	0.56	0.41
	1.01-2.00	1.16	0.25	0.2	0.012	0.24	0.37	0.087	0.092
	2.01-5.00	0.047	0.082	0.0013	0.0089	0.0021	0.034	0.21	0.0023
	> 5.00	0	0.02	0	0.0006	0	0	0.2	0

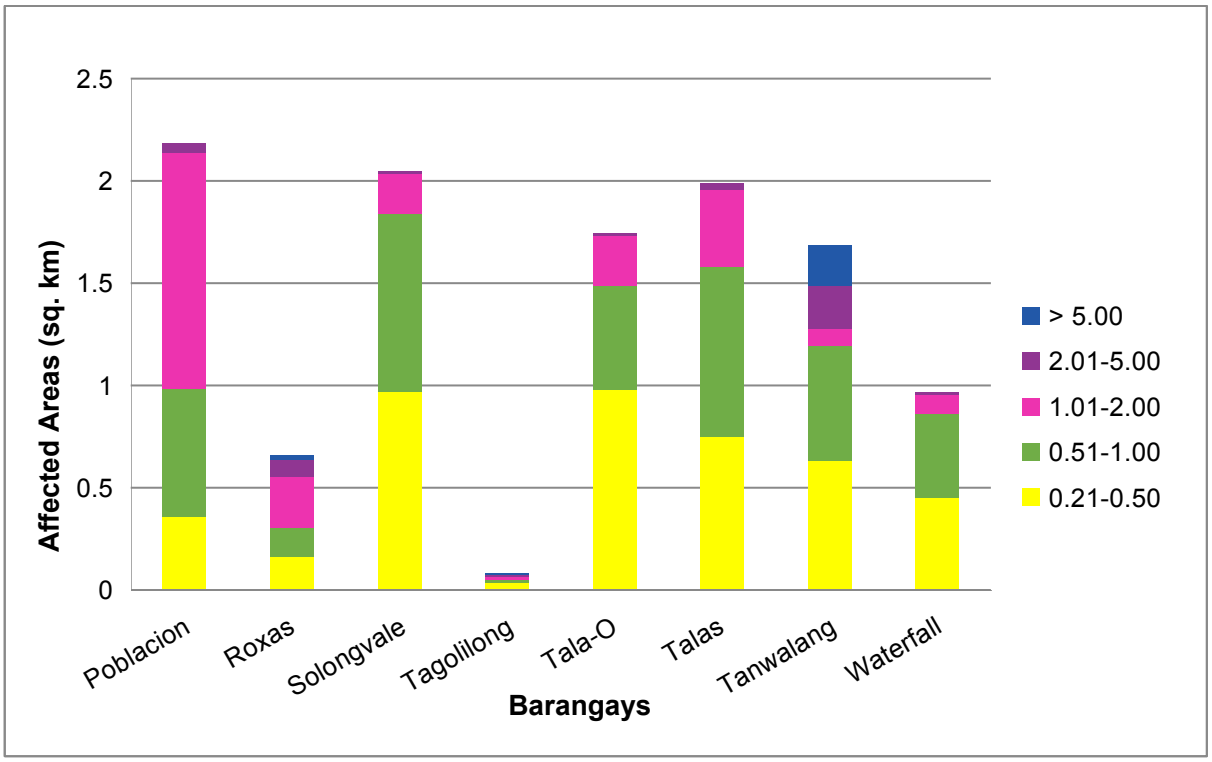


Figure 117. Affected Areas in Sulop, Davao del Sur during 25-Year Rainfall Return Period

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

Table 73. Affected Areas in Columbio, Sultan Kudarat during 25-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangay in Columbio
		Datablao
Affected Area (sq. km.)	0-0.20	1.38
	0.21-0.50	0.03
	0.51-1.00	0.019
	1.01-2.00	0.016
	2.01-5.00	0.023
	> 5.00	0.0071

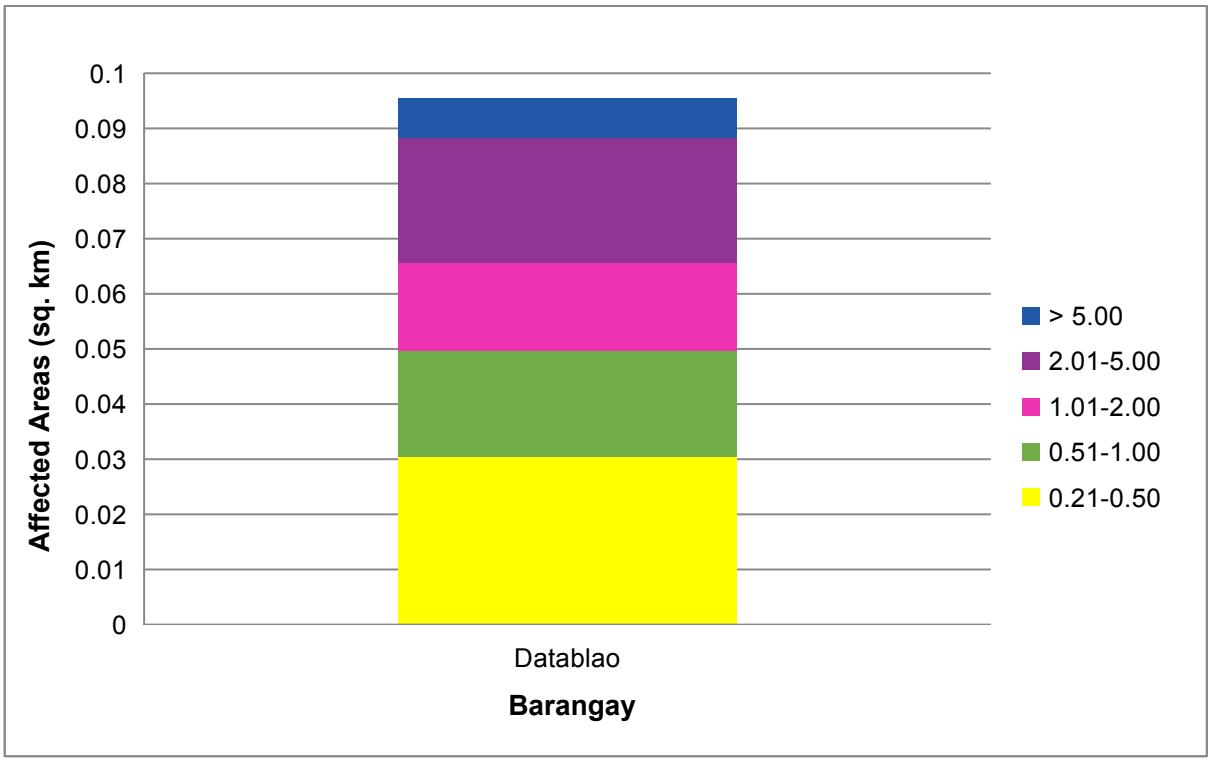


Figure 118. Affected Areas in Columbio, Sultan Kudarat during 25-Year Rainfall Return Period

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

Table 74. Affected Areas in Bansalan, Sultan Kudarat during 25-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Bansalan							
		Anonang	Bonifacio	Buenavista	Mabunga	New Clarin	Poblacion	Poblacion Dos	Union
Affected Area (sq. km.)	0-0.20	1.55	1.29	1.96	2.7	0.5	1.21	1.12	2.87
	0.21-0.50	0.16	0.16	0.34	2.28	0.064	0.22	0.61	0.36
	0.51-1.00	0.11	0.069	0.24	0.4	0.058	0.17	0.23	0.32
	1.01-2.00	0.051	0.04	0.083	0.2	0.067	0.094	0.054	0.32
	2.01-5.00	0.021	0.017	0.046	0.064	0.018	0.076	0.0016	0.091
	> 5.00	0	0.0008	0.0013	0.0004	0	0.011	0	0.01

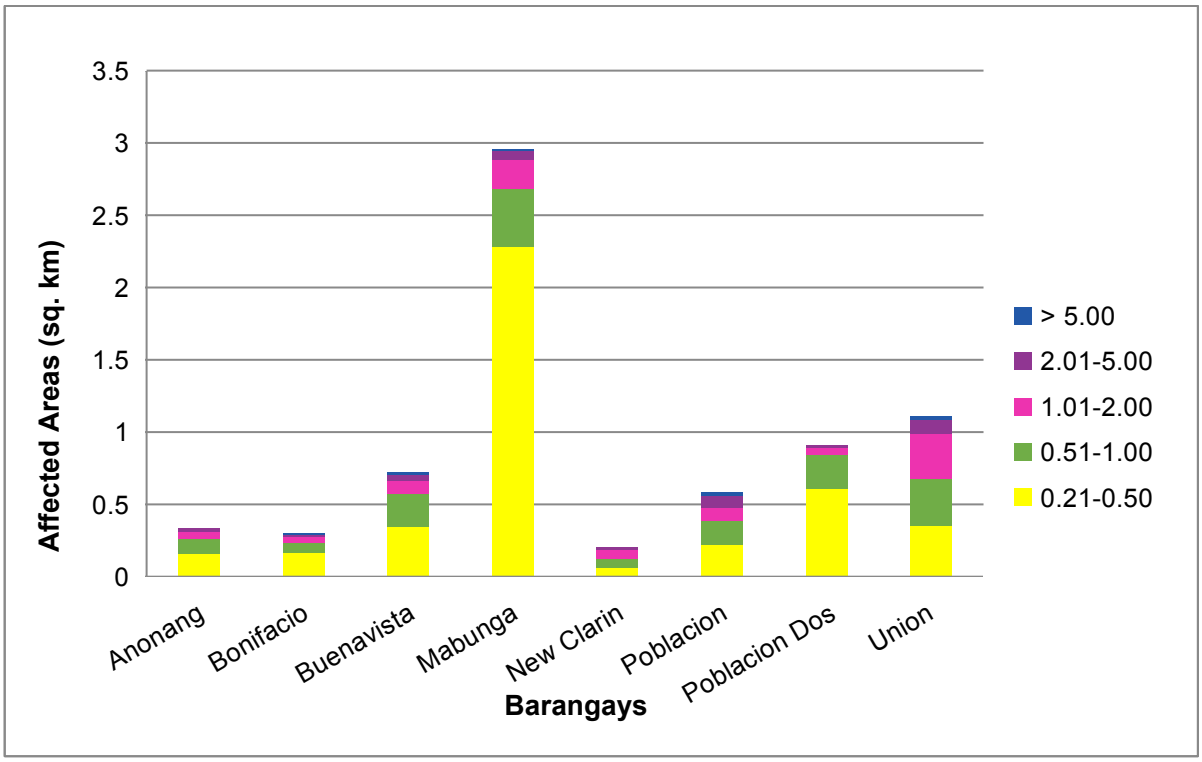


Figure 119. Affected Areas in Bansalan, Davao del Sur during 100-Year Rainfall Return Period

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

Table 75. Affected Areas in Digos City, Davao del Sur during 100-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Digos City											
		Aplaya	Balabag	Cogon	Colorado	Dawis	Dulangan	Goma	Igpit	Kiagot	Lungag	Mahayahay	Matti
Affected Area (sq. km.)	0-0.20	1.59	0.11	1.79	3.35	1.37	0.04	2.23	0.81	1.9	4.56	4.06	4.32
	0.21-0.50	1.63	0.0029	1.04	0.92	1.22	0.023	0.48	0.77	0.084	0.35	0.45	0.83
	0.51-1.00	1.23	0.0023	1.83	1.6	0.39	0.039	0.21	1	0.031	0.25	0.27	0.65
	1.01-2.00	0.16	0.0031	0.47	1.35	0.072	0.0033	0.14	1.4	0.038	0.1	0.2	0.6
	2.01-5.00	0.079	0.00033	0.016	0.3	0.026	0.00089	0.059	0.3	0.032	0.053	0.14	0.36
	> 5.00	0.017	0	0	0.0051	0	0	0	0	0.002	0	0.0074	0.013

DIGOS - PADADA BASIN		Affected Barangays in Digos City											
		Ruparan	San Agustin	San Jose	San Miguel	San Roque	Sinawilan	Soong	Tiguman	Tres de Mayo	Zone 1	Zone 2	Zone 3
Affected Area (sq. km.)	0-0.20	2.94	3.52	1.01	0.49	4.85	3.3	0.78	0.87	1.87	2.1	0.64	1.4
	0.21-0.50	0.23	1.1	1.18	1.03	0.71	0.44	0.036	1.06	0.47	0.077	0.44	1.11
	0.51-1.00	0.095	0.43	0.39	0.76	0.51	0.53	0.014	0.55	0.46	0.05	0.22	0.24
	1.01-2.00	0.063	0.24	0.35	0.48	0.26	0.12	0.0081	0.21	0.3	0.035	0.07	0.016
	2.01-5.00	0.06	0.13	0.012	0	0.081	0.046	0.0079	0.0012	0.19	0.048	0.095	0.0068
	> 5.00	0.0069	0.01	0	0	0.0002	0.011	0.0001	0	0.099	0.01	0.16	0.01

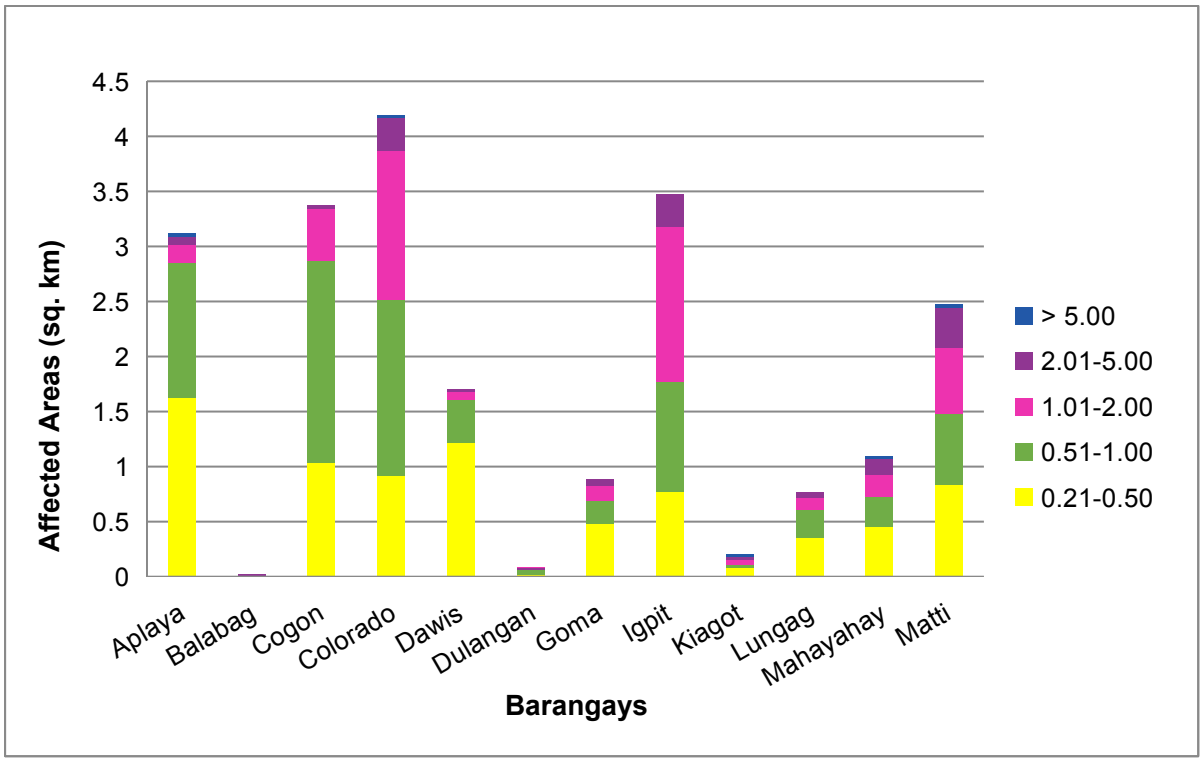


Figure 120. Affected Areas in Digos City, Davao del Sur during 100-Year Rainfall Return Period

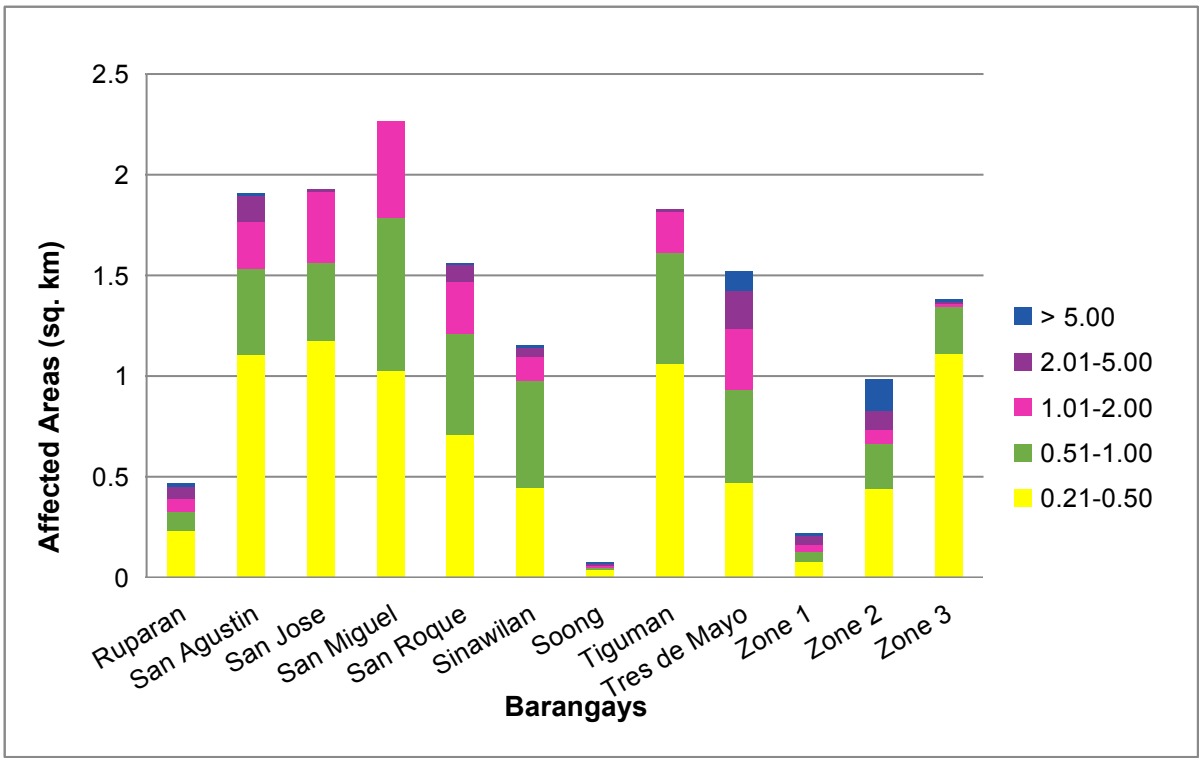


Figure 121. Affected Areas in Digos City, Davao del Sur during 100-Year Rainfall Return Period

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

Table 76. Affected Areas in Hagonoy, Davao del Sur during 100-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Hagonoy										
		Balutakay	Clib	Guihing	Guihing Aplaya	Hagonoy Crossing	Kibuaya	La Union	Lanuro	Lapulabao	Leling	Mahayahay
Affected Area (sq. km.)	0-0.20	0.32	2.34	0.89	2.13	1.08	1.16	2.9	0.67	2.34	2.85	1.44
	0.21-0.50	0.44	0.2	0.8	1.64	1.01	0.63	0.36	1.22	1.19	3.74	0.66
	0.51-1.00	0.59	0.2	0.48	1.07	0.26	1.68	0.18	0.65	0.86	2.34	0.32
	1.01-2.00	1.45	0.53	0.092	0.39	0.24	2.06	0.3	0.83	0.45	3.05	0.029
	2.01-5.00	1.72	0.17	0.084	0.085	0.089	0.45	0.094	0.77	0.041	1.81	0.016
	> 5.00	0	0.038	0.17	0.024	0.24	0.0022	0.014	0	0.0027	0	0.0018

DIGOS - PADADA BASIN		Affected Barangays in Hagonoy									
		Malabang Damsite	Maliit Digos	New Quezon	Paligue	Poblacion	Sacub	San Guillermo	San Isidro	Sinayawan	Tologan
Affected Area (sq. km.)	0-0.20	2.23	1.36	2.31	0.34	1.55	2.12	0.66	0.015	0.51	0.54
	0.21-0.50	0.25	0.33	0.57	0.55	1.67	3.08	0.087	0.02	0.72	0.37
	0.51-1.00	0.26	0.46	0.22	0.35	0.4	1.71	0.18	0.13	0.64	0.28
	1.01-2.00	0.24	0.68	0.29	0.082	0.1	0.031	0.53	1.26	0.98	0.091
	2.01-5.00	0.089	0.065	1.58	0.0002	0.058	0	0.27	1.09	0.17	0.096
	> 5.00	0.0024	0.0003	0.029	0	0.022	0	0.019	0	0	0.14

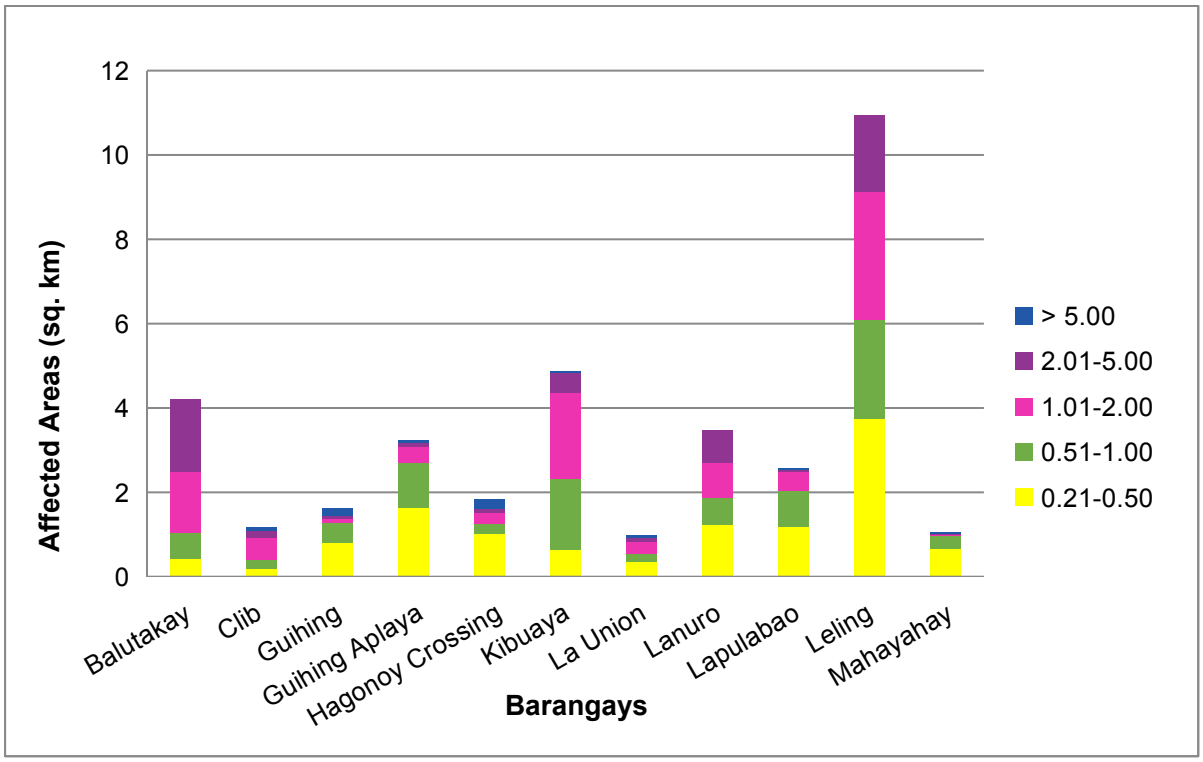


Figure 122. Affected Areas in Hagonoy, Davao del Sur during 100-Year Rainfall Return Period

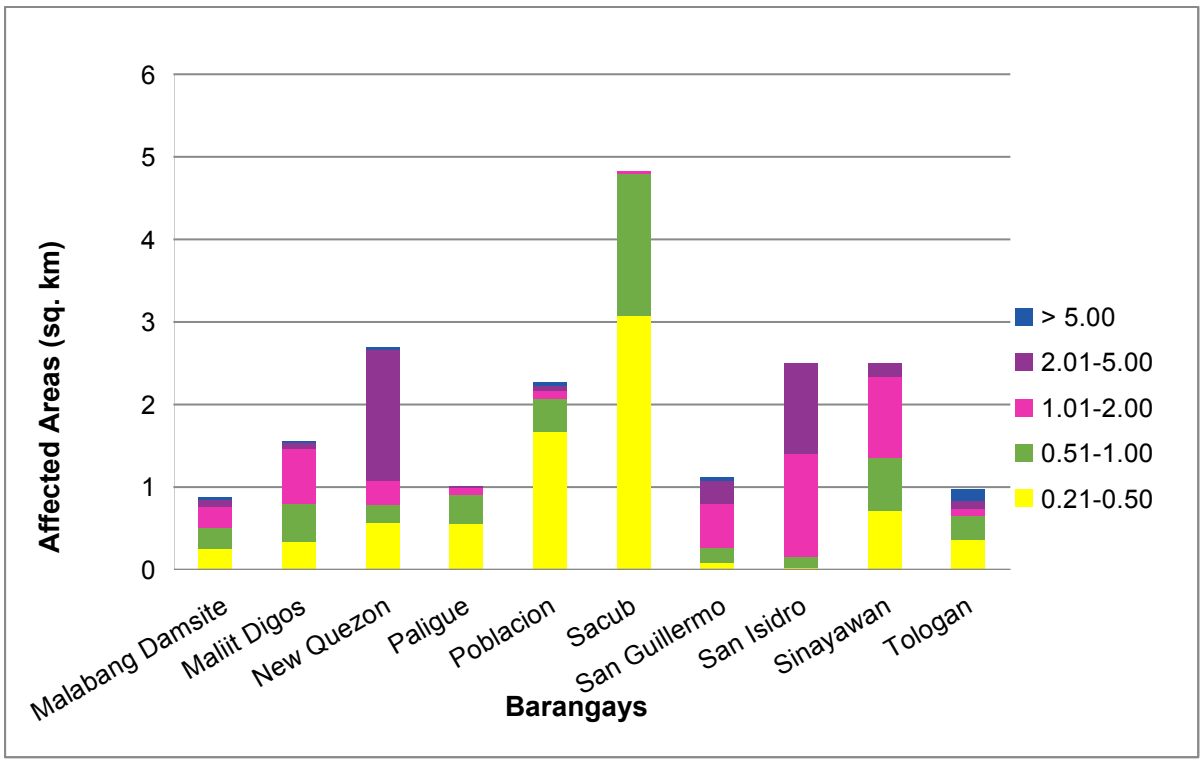


Figure 123. Affected Areas in Hagonoy, Davao del Sur during 100-Year Rainfall Return Period

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

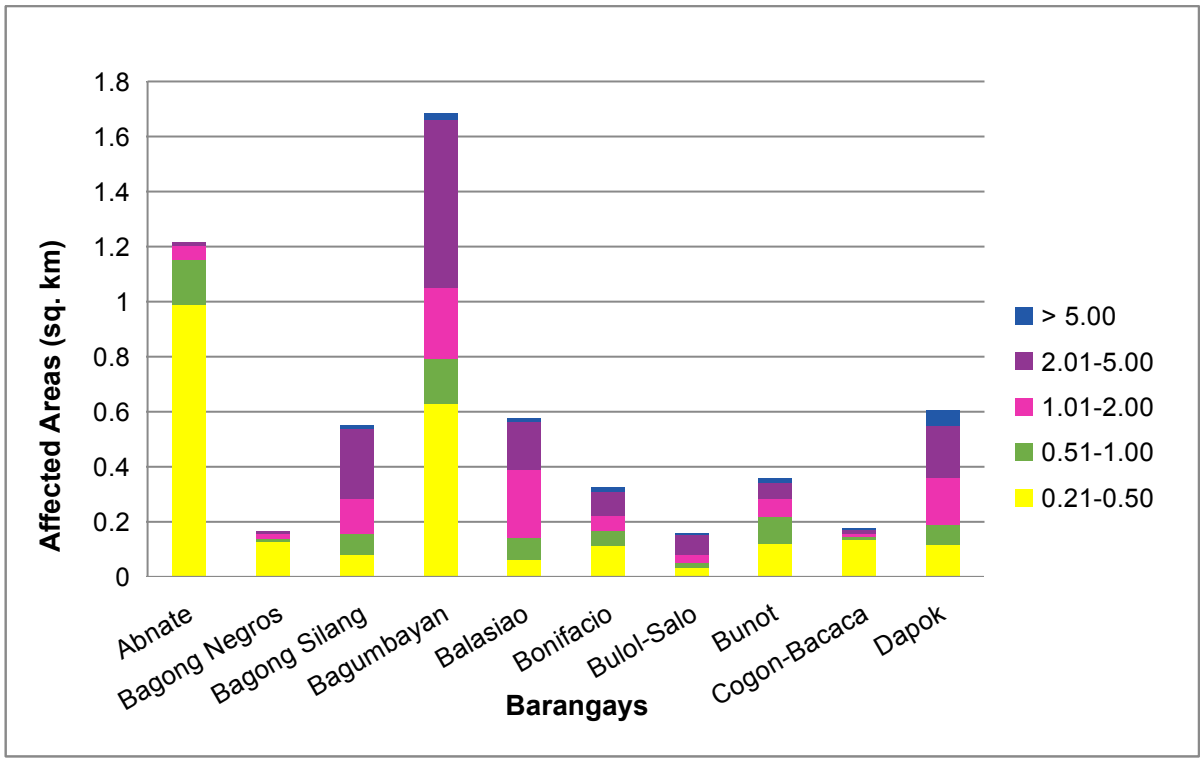


Figure 124. Affected Areas in Kiblawan, Davao del Sur during 100-Year Rainfall Return Period

Table 77. Affected Areas in Hagonoy, Davao del Sur during 100-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Kiblawan									
		Abnate	Bagong Negros	Bagong Silang	Bagumbayan	Balasiao	Bonifacio	Bulol-Salo	Bunot	Cogon-Bacaca	Dapok
Affected Area (sq. km.)	0-0.20	2.17	1.18	1.25	4.38	1.61	2.22	0.85	2.6	0.47	1.59
	0.21-0.50	0.99	0.13	0.08	0.63	0.063	0.11	0.035	0.12	0.14	0.12
	0.51-1.00	0.16	0.012	0.076	0.16	0.08	0.052	0.019	0.097	0.0093	0.069
	1.01-2.00	0.054	0.016	0.13	0.26	0.25	0.056	0.026	0.065	0.01	0.17
	2.01-5.00	0.0043	0.0084	0.25	0.61	0.18	0.087	0.074	0.061	0.014	0.19
	> 5.00	0	0	0.012	0.024	0.0044	0.016	0.0071	0.018	0.0002	0.058

DIGOS - PADADA BASIN		Affected Barangays in Kiblawan									
		Ihan	Kibongbong	Kimlawis	Kisulan	Lati-An	Manual	Maraga-A	Molopolo	New Sibonga	Panaglib
Affected Area (sq. km.)	0-0.20	0.32	0.55	1.38	0.84	1.12	0.86	1.42	2.27	1.41	0.43
	0.21-0.50	0.08	0.29	0.032	0.075	0.046	0.79	0.055	0.21	0.098	0.027
	0.51-1.00	0.078	0.033	0.018	0.014	0.046	0.091	0.029	0.057	0.093	0.024
	1.01-2.00	0.11	0.018	0.022	0.014	0.12	0	0.044	0.098	0.27	0.061
	2.01-5.00	0.16	0.022	0.048	0.0071	0.2	0	0.078	0.19	0.5	0.29
	> 5.00	0.049	0.0054	0.01	0	0.097	0	0.0014	0.017	0.046	0.35

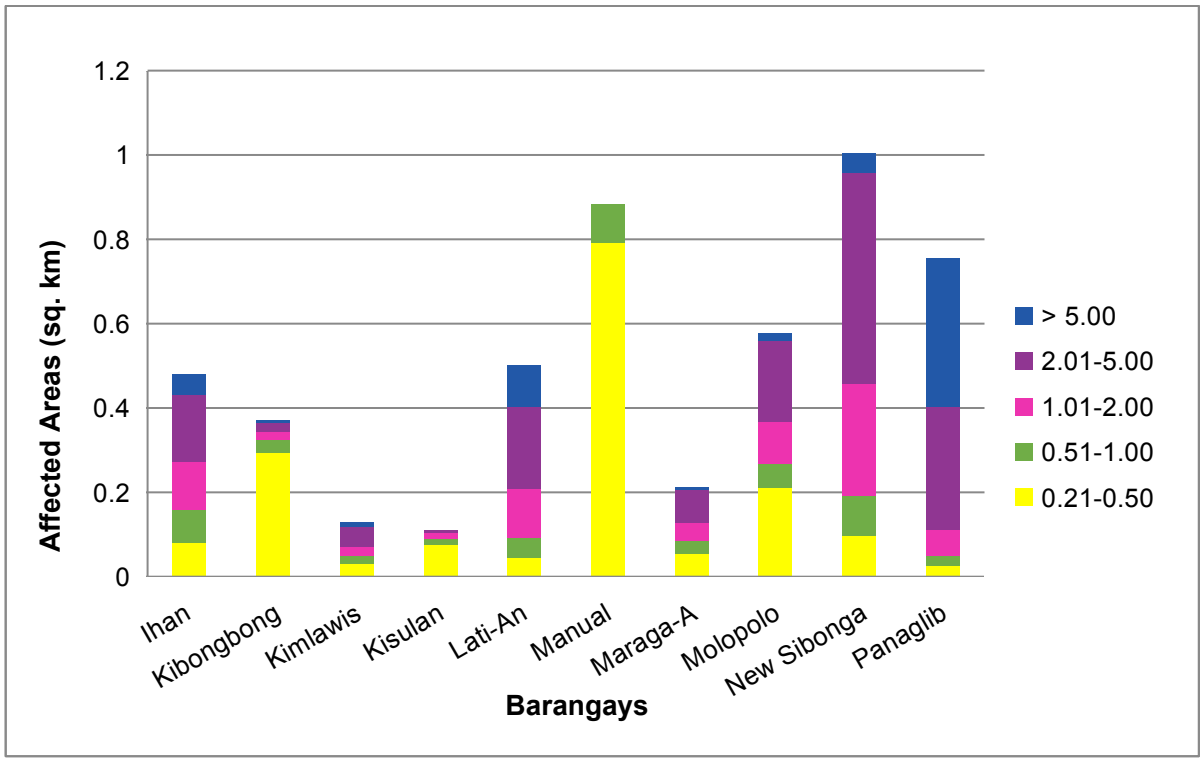


Figure 125. Affected Areas in Kiblawan, Davao del Sur during 100-Year Rainfall Return Period

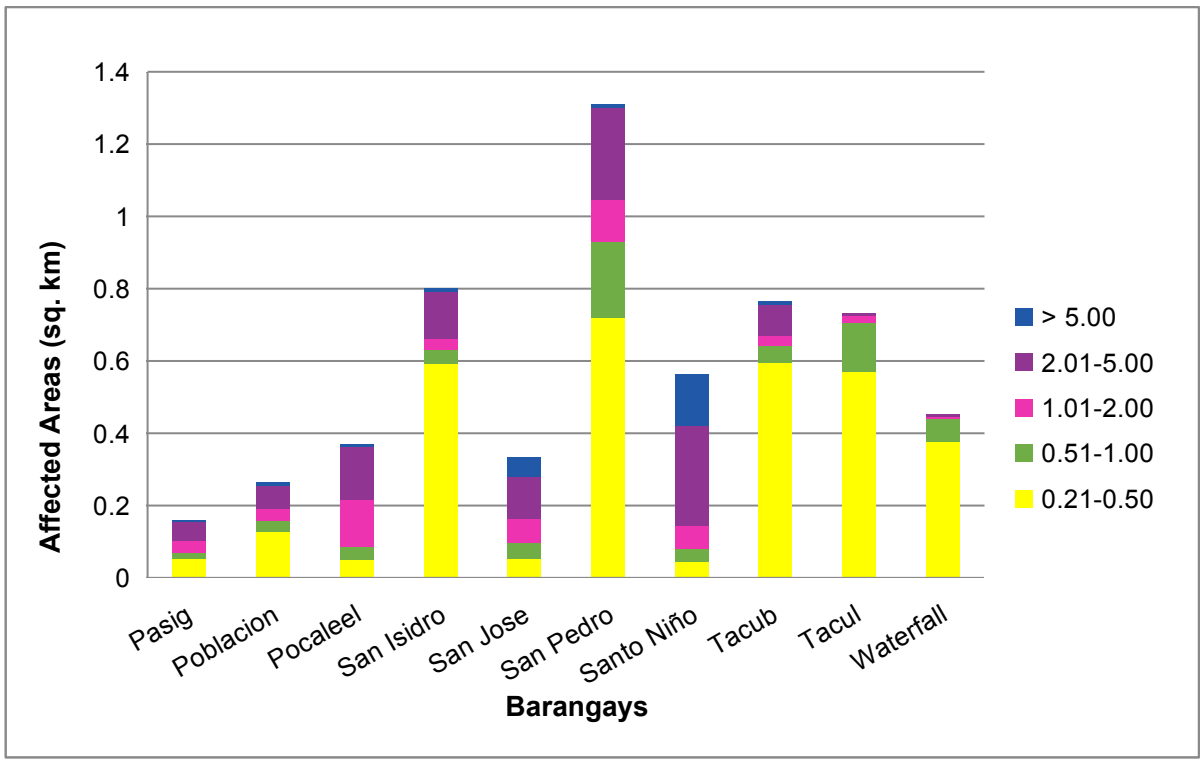


Figure 126. Affected Areas in Kiblawan, Davao del Sur during 100-Year Rainfall Return Period

Table 78. Affected Areas in Hagonoy, Davao del Sur during 100-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Kiblawan									
		Pasig	**Poblacion**	**Pocaleel**	**San Isidro**	**San Jose**	**San Pedro**	**Santo Niño**	**Tacub**	**Tacul**	**Waterfall**
Affected Area (sq. km.)	0-0.20	0.55	1.6	1.14	0.91	0.73	2.85	1.04	1.05	0.55	0.46
	0.21-0.50	0.054	0.13	0.049	0.59	0.053	0.72	0.043	0.6	0.57	0.38
	0.51-1.00	0.015	0.03	0.038	0.039	0.044	0.21	0.038	0.045	0.14	0.064
	1.01-2.00	0.032	0.035	0.13	0.031	0.069	0.11	0.062	0.029	0.021	0.0035
	2.01-5.00	0.052	0.063	0.15	0.13	0.11	0.26	0.28	0.086	0.0013	0.0011
	> 5.00	0.00029	0.01	0.00066	0.0051	0.054	0.0084	0.14	0.01	0	0

For the 100-year return period, 0.27% of the municipality of Magsaysay with an area of 109.8 sq. km. will experience flood levels of less than 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters while 0.03%, 0.02%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 79. Affected Areas in Magsaysay, Davao del Sur during 100-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangay in Magsaysay
		New Ilocos
Affected Area (sq. km.)	0-0.20	0.3
	0.21-0.50	0.07
	0.51-1.00	0.03
	1.01-2.00	0.018
	2.01-5.00	0.011
	> 5.00	0

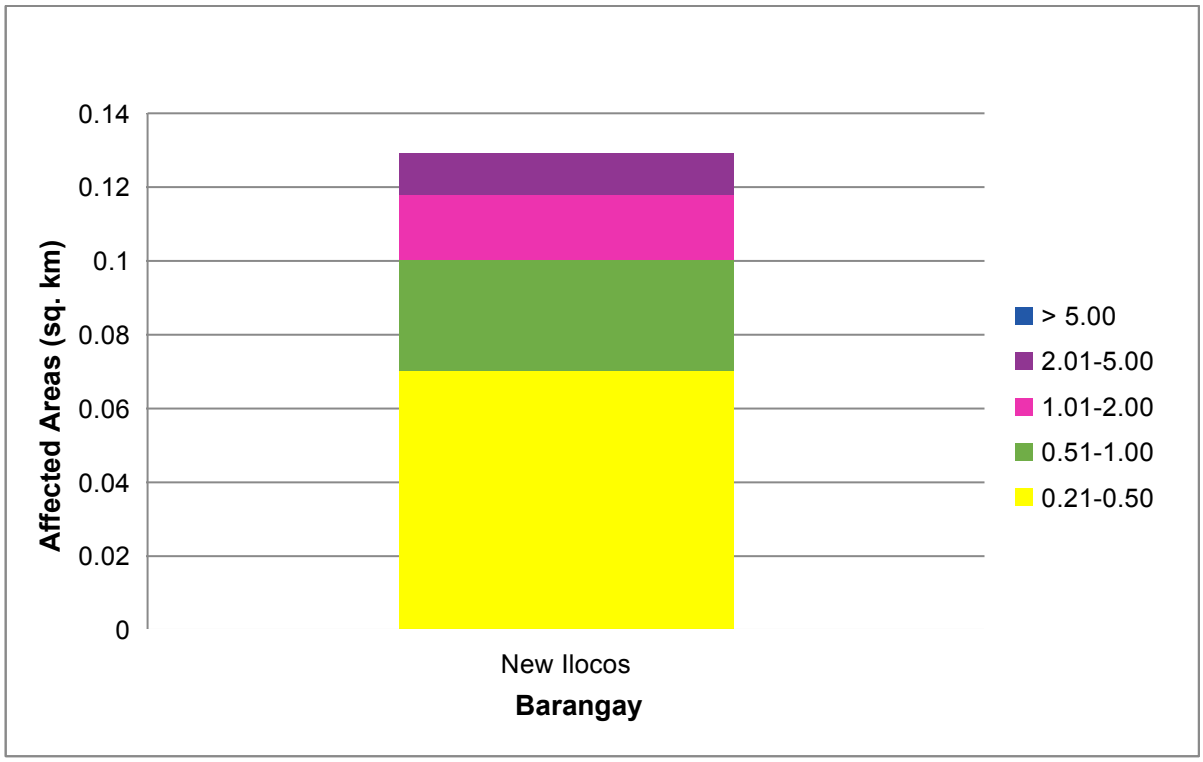


Figure 127. Affected Areas in Magsaysay, Davao del Sur during 100-Year Rainfall Return Period

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

Table 80. Affected Areas in Malalag, Davao del Sur during 100-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Malalag					
		Bagumbayan	Bolton	Kiblagon	Lapu-Lapu	Mabini	New Baclayon
Affected Area (sq. km.)	0-0.20	0.014	0.51	11.18	29.15	1.34	2.10
	0.21-0.50	0.0038	0.096	3.076	1.92	0.050	0.43
	0.51-1.00	0.0095	0.058	3.78	1.105	0.021	0.64
	1.01-2.00	0.0047	0.021	2.57	1.5007	0.016	0.905
	2.01-5.00	0	0.016	0.8	2.53	0.016	0.067
	> 5.00	0	0.0014	0.0505	0.63	0.0094	0

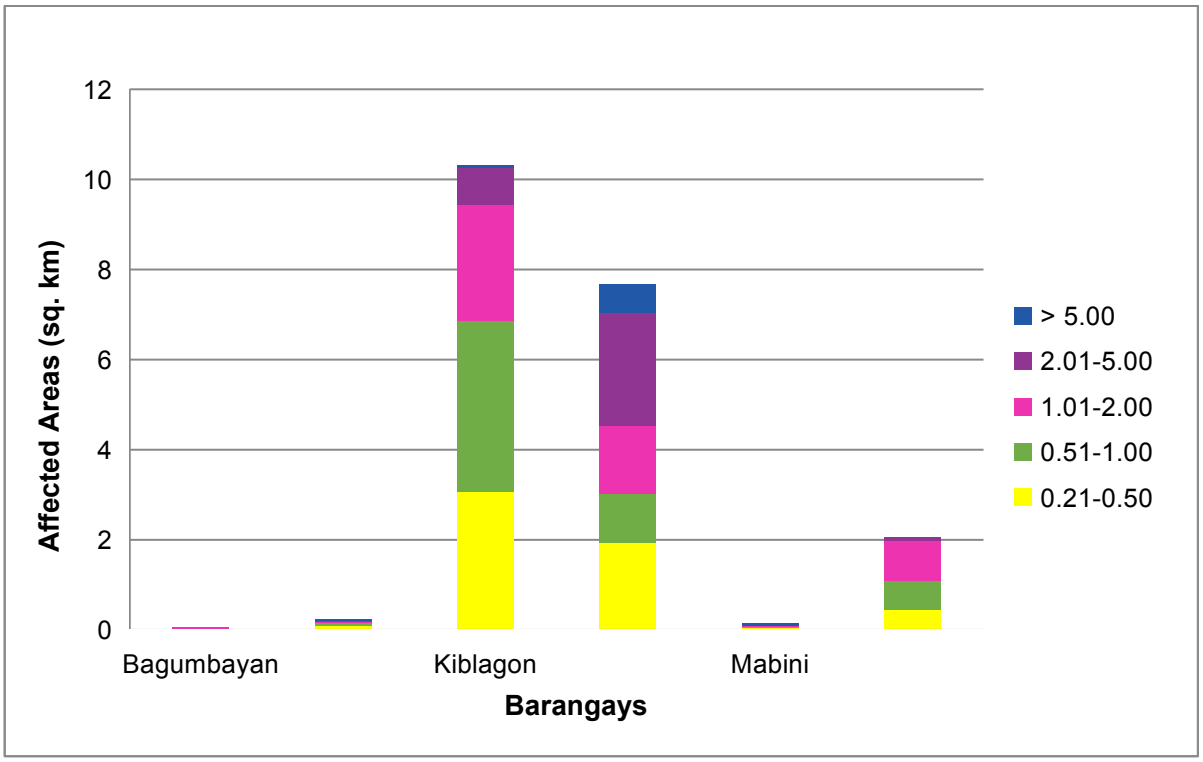


Figure 128. Affected Areas in Malalag, Davao del Sur during 100-Year Rainfall Return Period

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

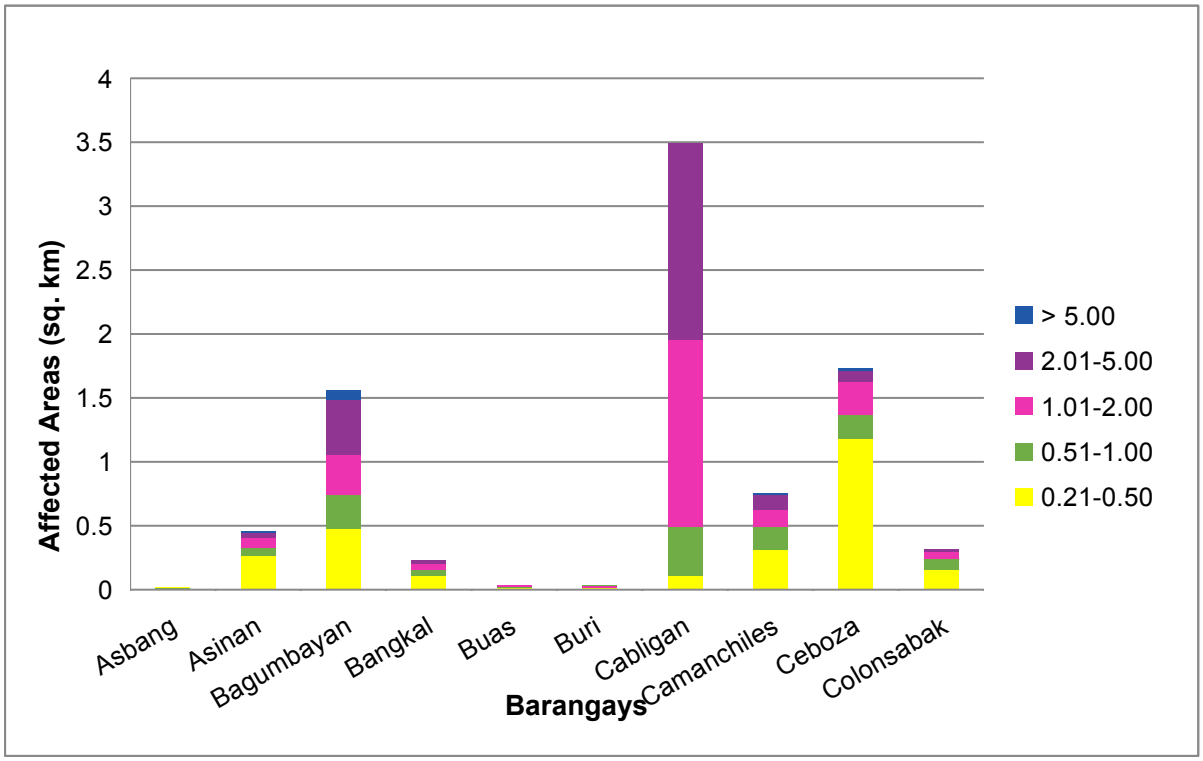


Figure 129. Affected Areas in Matanao, Davao del Sur during 100-Year Rainfall Return Period

Table 81. Affected Areas in Matanao, Davao del Sur during 100-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Matanao									
		Asbang	Asinan	Bagumbayan	Bangkal	Buas	Buri	Cabligan	Camanchiles	Ceboza	Colonsabak
Affected Area (sq. km.)	0-0.20	0.039	0.89	2.65	0.61	0.081	0.097	0.04	2.03	2.07	0.63
	0.21-0.50	0.0018	0.27	0.48	0.11	0.016	0.012	0.11	0.31	1.18	0.16
	0.51-1.00	0.00015	0.06	0.26	0.049	0.003	0.004	0.39	0.19	0.19	0.085
	1.01-2.00	0	0.076	0.32	0.047	0.00081	0.0001	1.46	0.13	0.25	0.055
	2.01-5.00	0	0.042	0.43	0.027	0	0	1.54	0.12	0.088	0.02
	> 5.00	0	0.00021	0.076	0	0	0	0	0.015	0.023	0

DIGOS - PADADA BASIN		Affected Barangays in Matanao									
		Dongan-Pekong	Kabasagan	Kapok	Kibao	La Suerte	Langa-An	Lower Marber	Manga	New Katipunan	New Visayas
Affected Area (sq. km.)	0-0.20	2.59	0.96	0.42	0.97	1.61	1.05	1.07	5.09	5.22	1.76
	0.21-0.50	0.26	0.26	0.1	0.091	0.34	0.58	0.15	1.04	0.61	1.18
	0.51-1.00	0.11	0.033	0.018	0.033	0.55	0.057	0.15	1.99	0.36	0.23
	1.01-2.00	0.26	0.021	0.021	0.062	0.33	0.021	0.13	2.13	0.32	0.0031
	2.01-5.00	0.18	0.0079	0.016	0.054	0.15	0.03	0.16	2.58	0.32	0.0007
	> 5.00	0.0044	0	0	0.0056	0.054	0.00093	0.026	0.0048	0.059	0

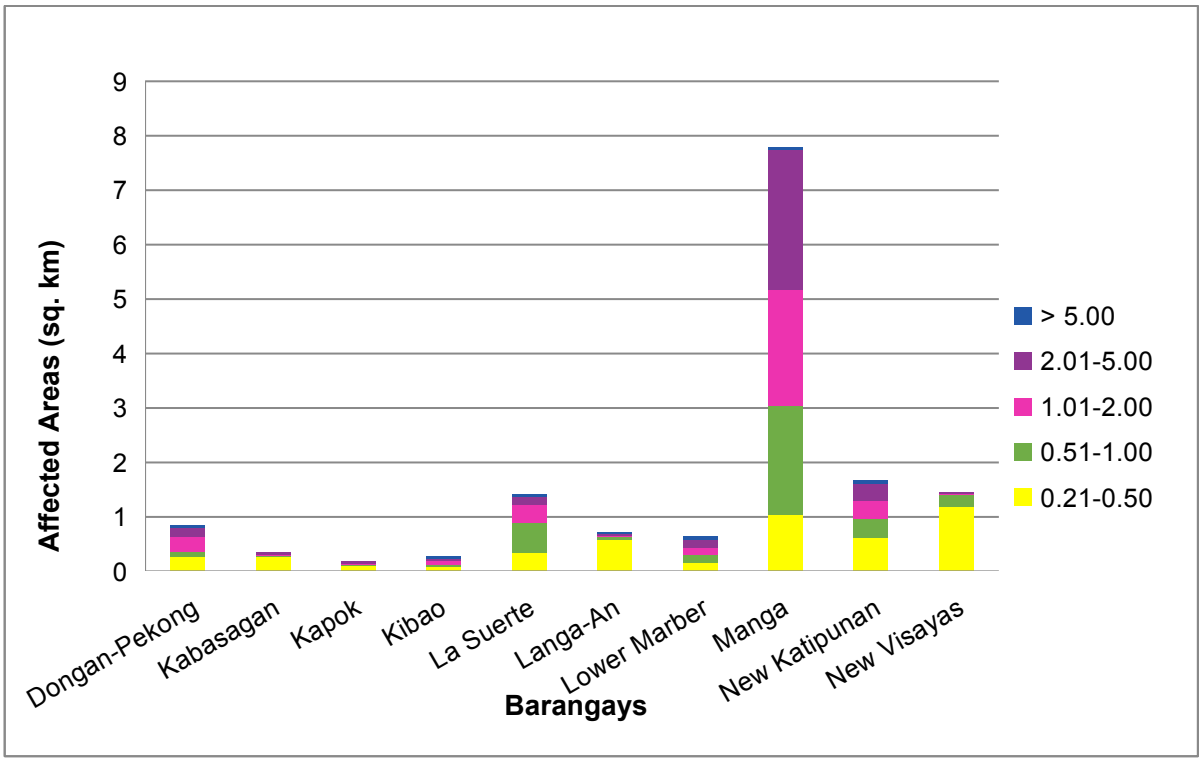


Figure 130. Affected Areas in Matanao, Davao del Sur during 100-Year Rainfall Return Peri

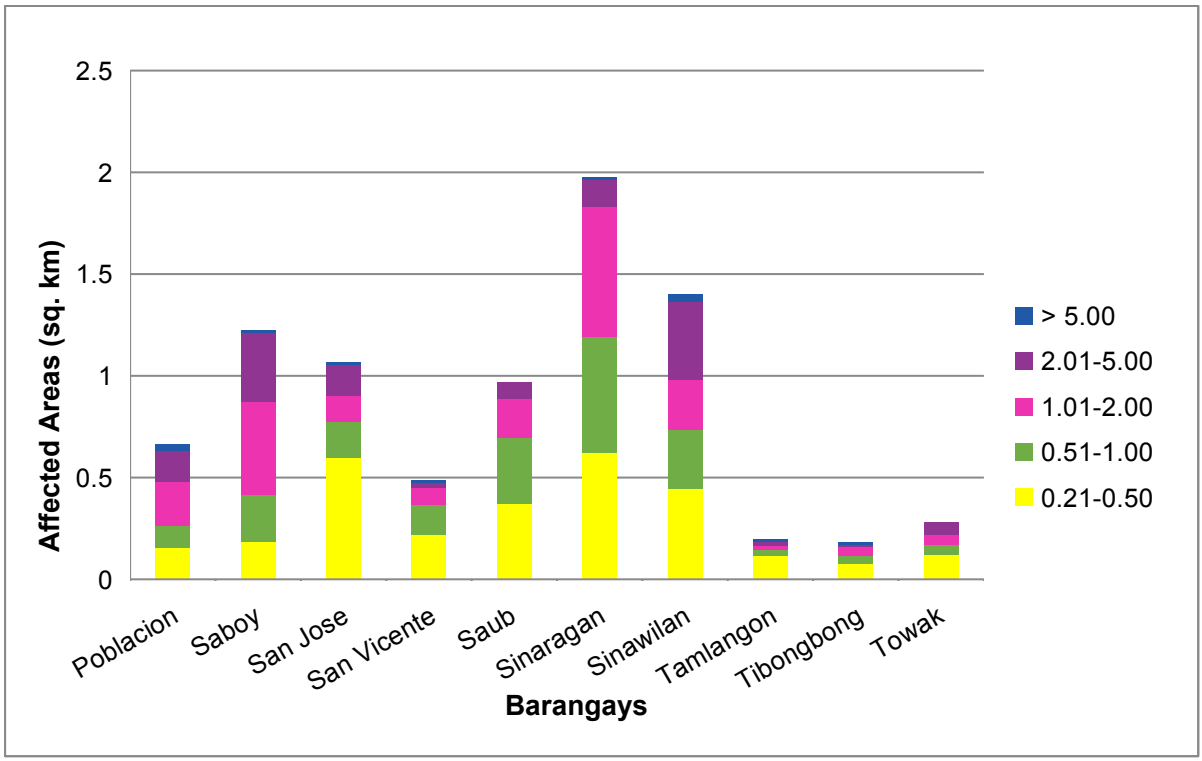


Figure 131. Affected Areas in Matanao, Davao del Sur during 100-Year Rainfall Return Peri

Table 82. Affected Areas in Matanao, Davao del Sur during 100-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Matanao									
		Poblacion	**Saboy**	**San Jose**	**San Vicente**	**Saub**	**Sinaragan**	**Sinawilan**	**Tamlangon**	**Tibongbong**	**Towak**
Affected Area (sq. km.)	0-0.20	1.12	0.62	2.3	1.33	0.99	3.9	5.78	0.7	1.16	0.98
	0.21-0.50	0.16	0.19	0.6	0.22	0.37	0.62	0.45	0.11	0.077	0.12
	0.51-1.00	0.11	0.23	0.17	0.15	0.32	0.57	0.29	0.033	0.039	0.047
	1.01-2.00	0.22	0.46	0.13	0.083	0.19	0.64	0.25	0.022	0.045	0.054
	2.01-5.00	0.15	0.34	0.16	0.026	0.082	0.13	0.38	0.015	0.012	0.063
	> 5.00	0.033	0.0029	0.0037	0.0009	0	0.0043	0.038	0.0029	0.00097	0

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

Table 83. Affected Areas in Padada, Davao del Sur during 100-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Padada								
		Almendras	Don Sergio Osmena, Sr.	Harada Butai	Lower Katipunan	Lower Limonzo	Lower Malinao	N C Ordaneza Distric	Northern Paligue	Palili
Affected Area (sq. km.)	0-0.20	0.35	0.99	1.87	3.8	0.86	2.58	0.52	0.89	3.69
	0.21-0.50	0.42	0.39	1.91	0.63	1.29	0.57	0.28	0.96	3.53
	0.51-1.00	0.16	0.4	1.26	0.28	0.48	0.41	0.082	1.09	1.55
	1.01-2.00	0.0074	0.7	0.42	0.17	0.081	0.54	0.022	0.18	0.32
	2.01-5.00	0	0.33	0.018	0.31	0.0045	0.9	0.0001	0.044	0.0032
	> 5.00	0	0.54	0	0.16	0	0.54	0	0.2	0

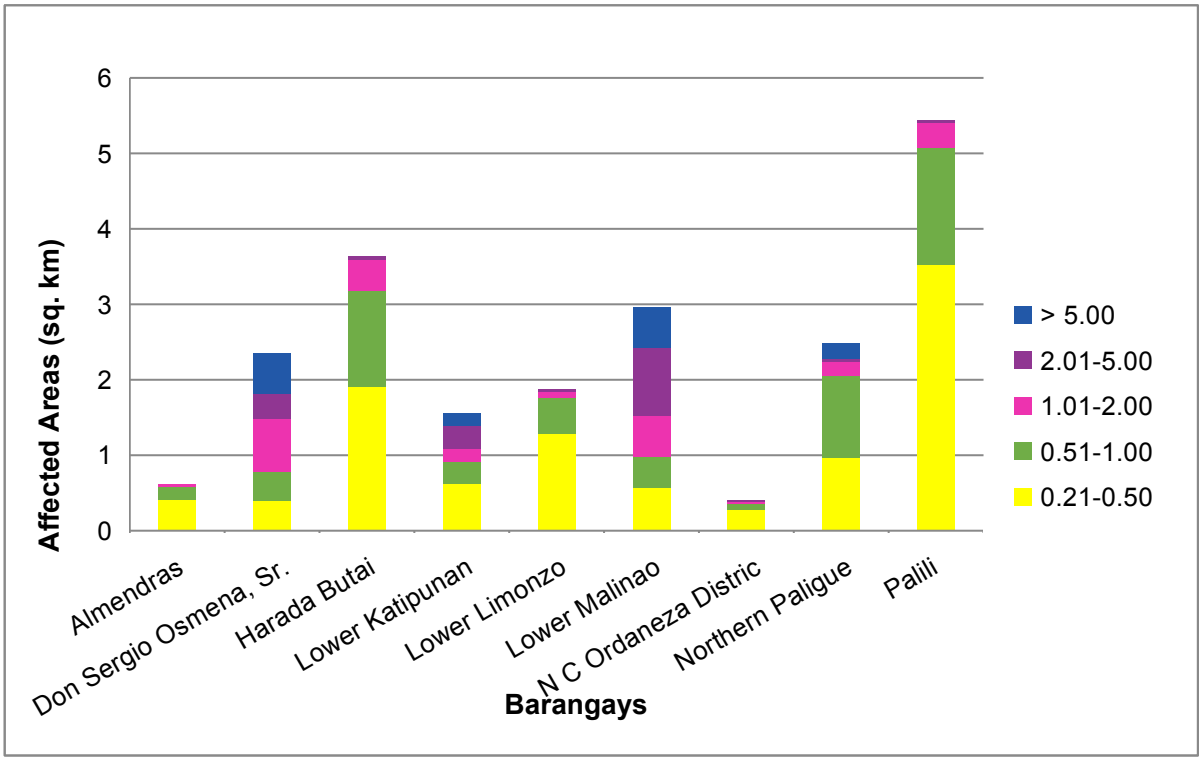


Figure 132. Affected Areas in Padada, Davao del Sur during 100-Year Rainfall Return Period

Table 84. Affected Areas in Padada, Davao del Sur during 100-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Padada							
		Piape	Punta Piape	Quirino District	San Isidro	Southern Paligue	Tulogan	Upper Limonzo	Upper Malinao
Affected Area (sq. km.)	0-0.20	0.39	1.73	0.44	1.03	0.96	0.73	1.61	2.12
	0.21-0.50	0.33	0.98	0.041	0.63	0.89	1.12	1.36	0.89
	0.51-1.00	0.45	0.59	0.011	0.54	0.39	0.5	0.41	0.12
	1.01-2.00	0.069	0.082	0	0.48	0.039	0.037	0.091	0.071
	2.01-5.00	0	0	0	0.023	0	0	0.013	0.057
	> 5.00	0	0	0	0	0	0	0	0

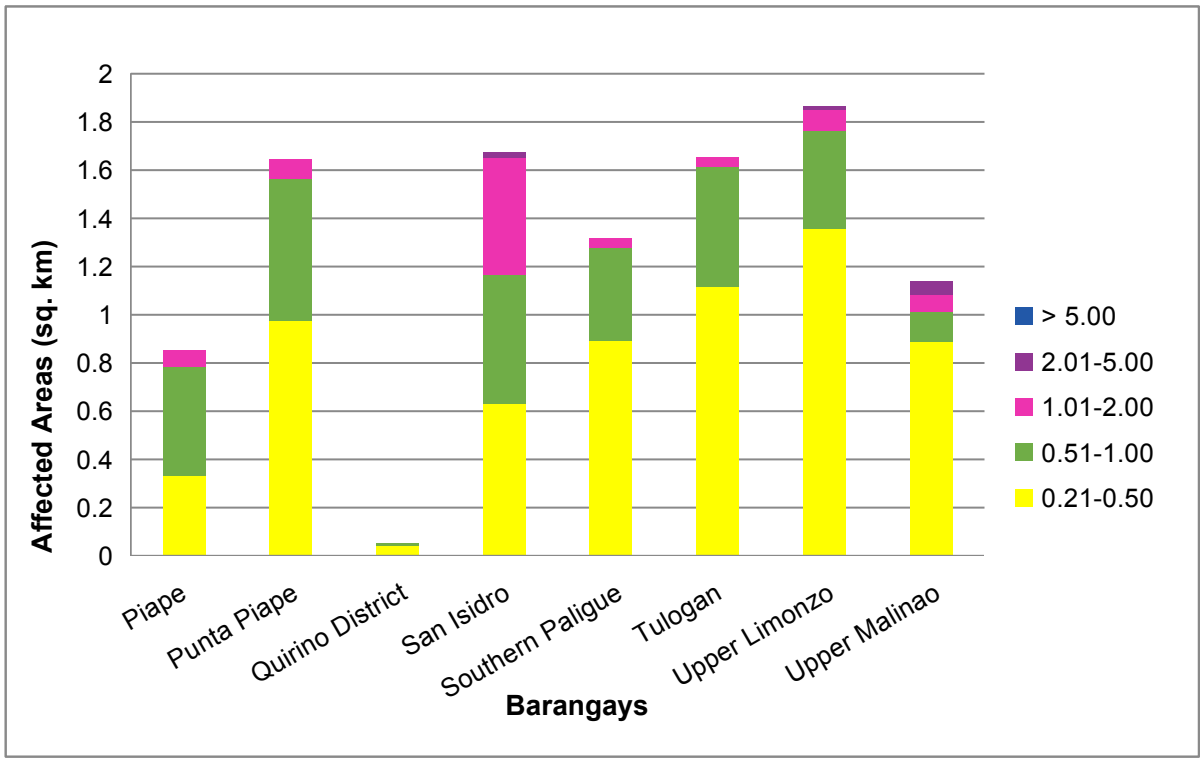


Figure 133. Affected Areas in Padada, Davao del Sur during 100-Year Rainfall Return Period

For the 100-year return period, 0.79% of the municipality of Santa Cruz with an area of 267.54 sq. km. will experience flood levels of less than 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.24%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 85. Affected Areas in Santa Cruz, Davao del Sur during 100-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Santa Cruz	
		Bato	Tagabuli
Affected Area (sq. km.)	0-0.20	2.07	0.041
	0.21-0.50	0.31	0.019
	0.51-1.00	0.31	0.0099
	1.01-2.00	0.63	0.011
	2.01-5.00	0.17	0
	> 5.00	0.012	0

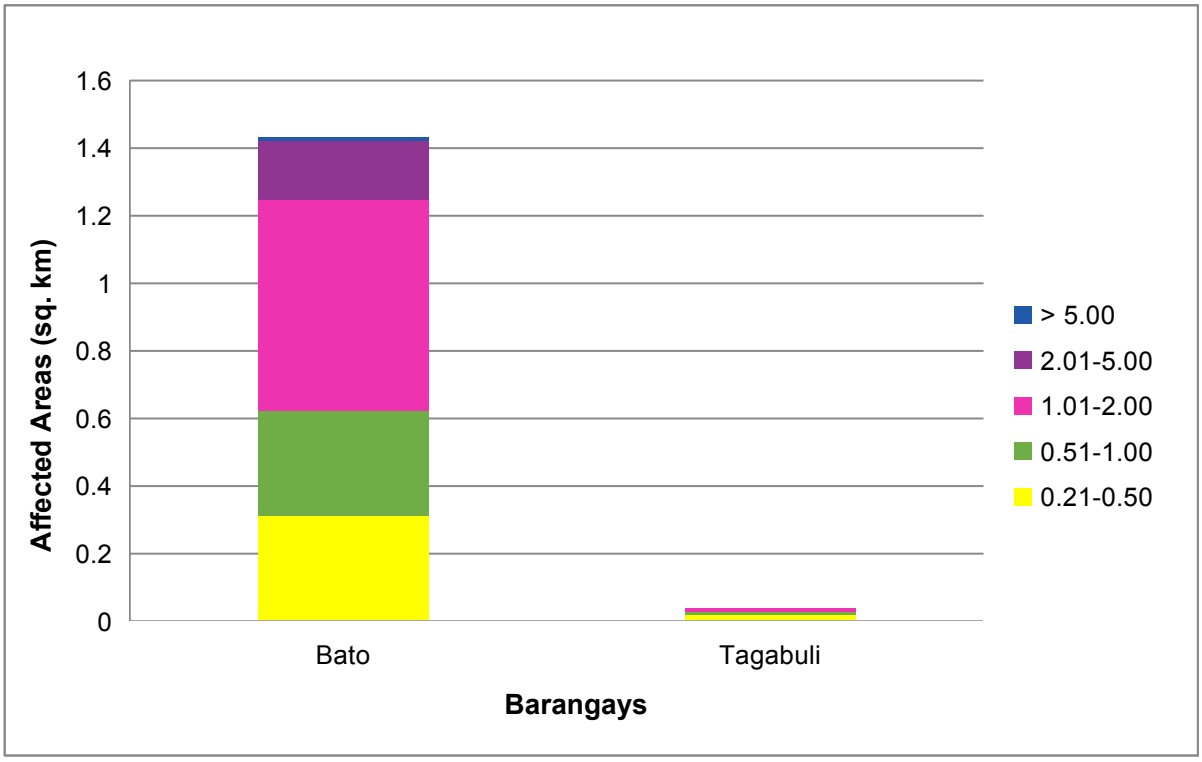


Figure 134. Affected Areas in Santa Cruz, Davao del Sur during 100-Year Rainfall Return Period

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

Table 86. Affected Areas in Sulop, Davao del Sur during 100-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Sulop								
		Balasinon	Buguis	Carre	Clib	Harada Butai	Katipunan	Kiblagon	Labon	Laperas
Affected Area (sq. km.)	0-0.20	0.15	1.14	0.87	0.51	1.18	0.76	0.15	0.46	0.73
	0.21-0.50	0.14	0.05	0.046	0.021	1.13	0.67	0.28	0.024	0.21
	0.51-1.00	0.15	0.028	0.033	0.011	0.96	0.25	0.73	0.012	0.24
	1.01-2.00	0.0075	0.036	0.028	0.0046	0.35	0.021	1.06	0.0081	0.016
	2.01-5.00	0	0.068	0.026	0.0017	0.014	0.05	0.087	0.0054	0.00074
	> 5.00	0	0.011	0.0065	0.0011	0	0.013	0	0.0026	0.00024

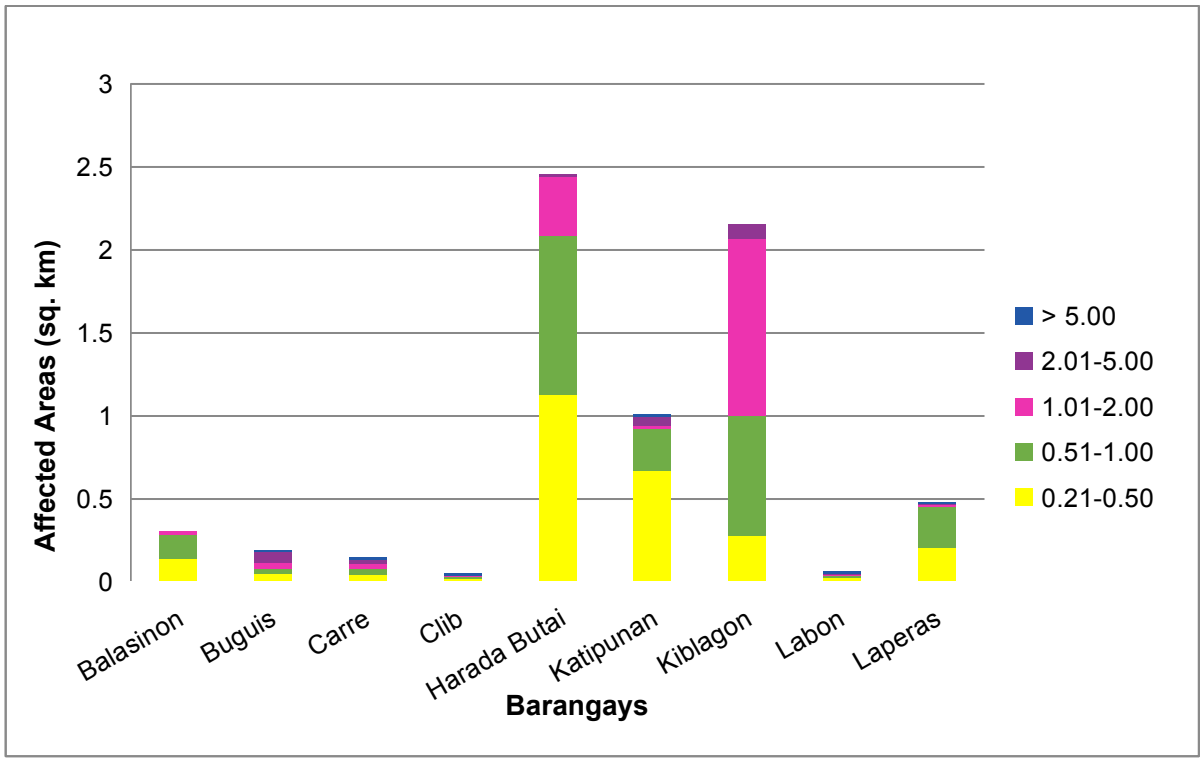


Figure 135. Affected Areas in Sulop, Davao del Sur during 100-Year Rainfall Return Period

Table 87. Affected Areas in Sulop, Davao del Sur during 100-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Sulop							
		Lapla	Litos	Luparan	Mckinley	New Cebu	Osmeña	Palili	Parame
Affected Area (sq. km.)	0-0.20	0.67	0.64	0.33	0.75	1.65	0.34	2.54	0.5
	0.21-0.50	0.027	0.025	0.013	0.041	0.24	0.015	3.25	0.015
	0.51-1.00	0.014	0.023	0.0052	0.036	0.55	0.0076	1.11	0.011
	1.01-2.00	0.013	0.027	0.0052	0.086	0.11	0.0048	1.21	0.012
	2.01-5.00	0.025	0.021	0.011	0.035	0.051	0.0015	0.61	0.017
	> 5.00	0.012	0.014	0.0059	0	0.0022	0	0	0.0009

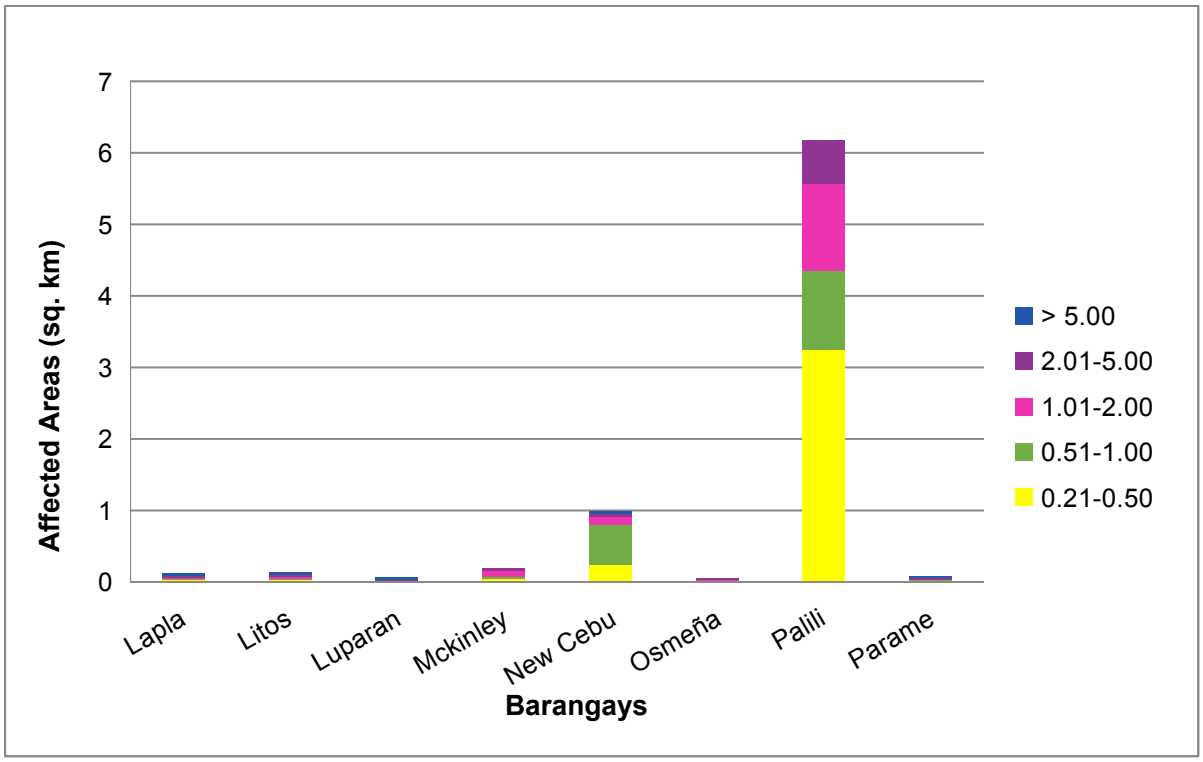


Figure 136. Affected Areas in Sulop, Davao del Sur during 100-Year Rainfall Return Period

Table 88. Affected Areas in Sulop, Davao del Sur during 100-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangays in Sulop							
		Poblacion	Roxas	Solongvale	Tagolilong	Tala-O	Talas	Tanwalang	Waterfall
Affected Area (sq. km.)	0-0.20	0.19	3.05	1.76	1.01	1.74	0.53	1.35	0.69
	0.21-0.50	0.27	0.15	0.84	0.042	1.14	0.64	0.49	0.43
	0.51-1.00	0.45	0.12	1.09	0.019	0.53	0.9	0.77	0.44
	1.01-2.00	1.14	0.25	0.29	0.013	0.37	0.55	0.11	0.15
	2.01-5.00	0.4	0.17	0.0029	0.011	0.011	0.1	0.21	0.004
	> 5.00	0	0.024	0	0.0007	0	0	0.22	0

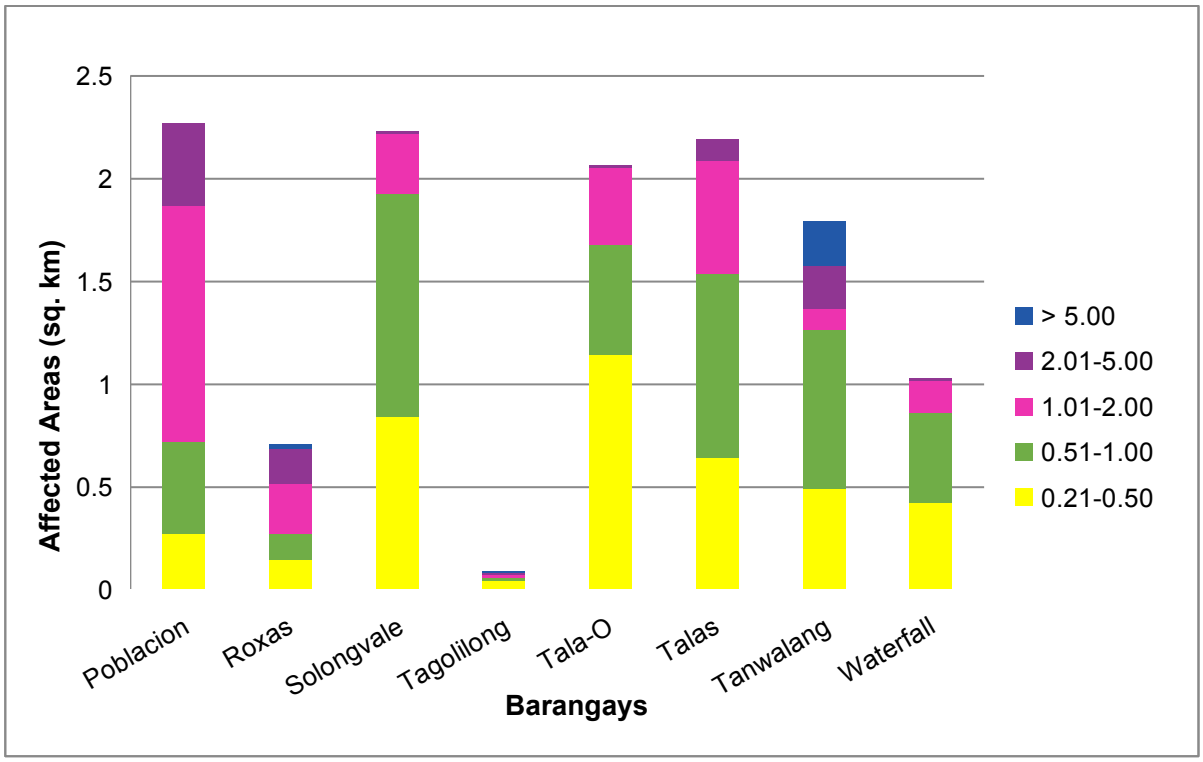


Figure 137. Affected Areas in Sulop, Davao del Sur during 100-Year Rainfall Return Period

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

Table 89. Affected Areas in Columbio, Sultan Kudarat during 100-Year Rainfall Return Period

DIGOS - PADADA BASIN		Affected Barangay in Columbio
		Datablao
Affected Area (sq. km.)	0-0.20	1.36
	0.21-0.50	0.036
	0.51-1.00	0.021
	1.01-2.00	0.017
	2.01-5.00	0.026
	> 5.00	0.0096

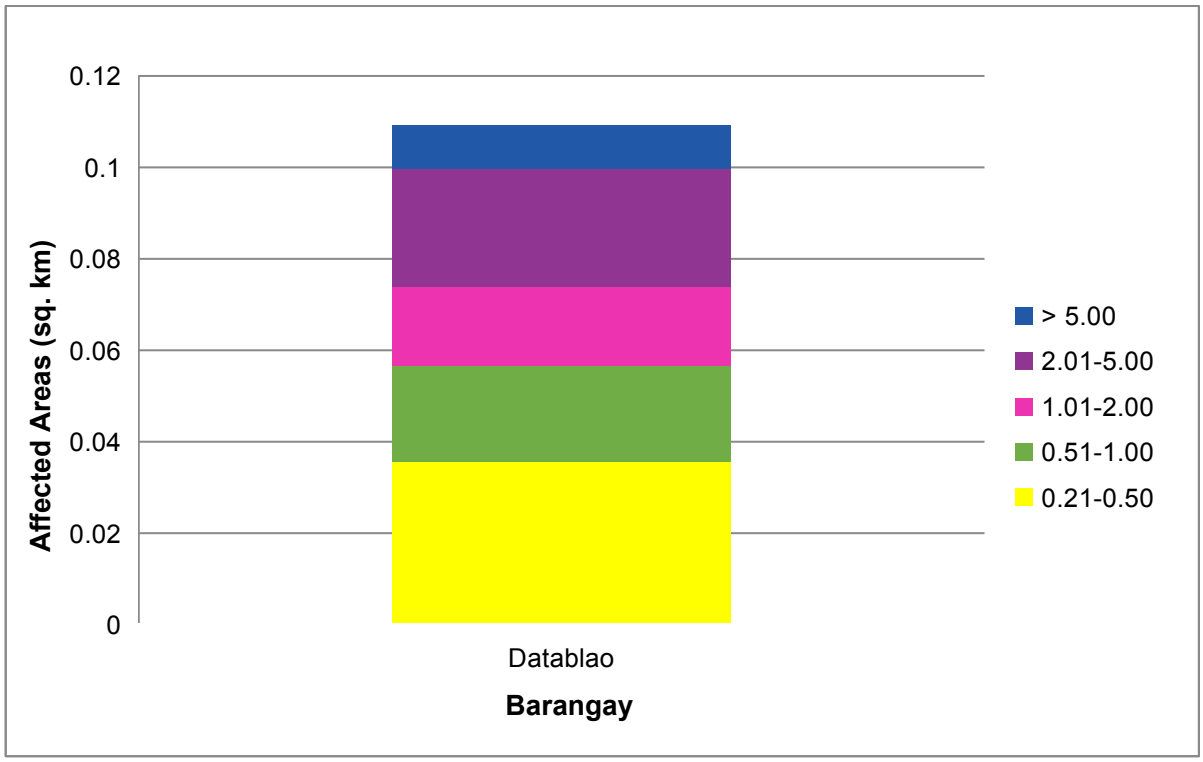


Figure 138. Affected Areas in Columbio, Sultan Kudarat during 100-Year Rainfall Return Period

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

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

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

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

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

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

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

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

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

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

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

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

Table 89. Area covered by each warning level with respect to the rainfall scenario

WARNING LEVEL	AREA COVERED IN SQ. KM.		
	5 YEAR	25 YEAR	100 YEAR
LOW	77.86	88.36	92.38
MEDIUM	64.82	79.54	89.35
HIGH	24.82	43.29	57.18
TOTAL	167.50	211.19	238.91

Of the 69 identified educational institutions in the Digos floodplain, five schools were assessed to be relatively prone to flooding as they are exposed to the Medium level flooding for all three rainfall scenarios. These are the United Church Of Christ In The Philippines Kindergarten Mission School in Brgy. Aplaya, Day Care Center in Brgy. Cogon, Polytechic College Davao Del Sur in Brgy. Zone 1, Day Care Center in Brgy. Zone 2 and Holy Cross Academy Inc. in Brgy. Zone 3. Five other institutions were found to be also susceptible to flooding, experiencing Low level flooding in the 5-year return period, and Medium level flooding in the 25- and 100-year rainfall scenarios. The list of educational institutions affected by flooding in Digos floodplain is found in Annex 12.

41 medical or health institutions were identified in the Digos floodplain. Digos Hospital (Canteen) in Brgy. Zone 2 and Zone 2 Health Center in Brgy. Zone 3 were found to be relatively prone to flooding, having Medium level flooding in all three rainfall scenarios. The list of health institutions affected by flooding in Digos floodplain is found in Annex 13.

5.7 Flood Validation

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

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

The validation personnel went to the specified points identified in a river basin and 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 through interview of some residents with knowledge of or have had experienced flooding in a particular area.

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

The flood validation consisted of 200 points randomly selected all over the Digos floodplain. It has an RMSE value of 1.07.

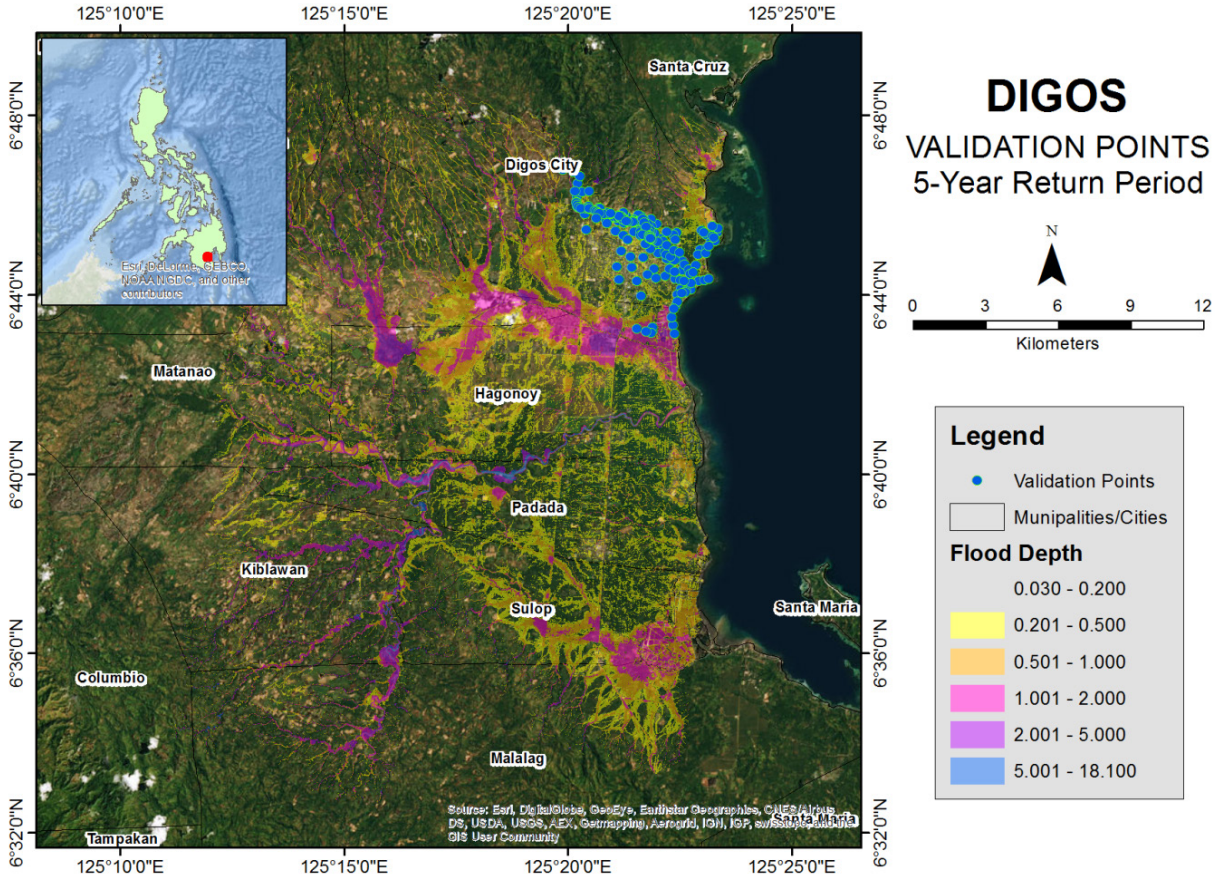


Figure 139. Flood Validation Points of Digos River Basin

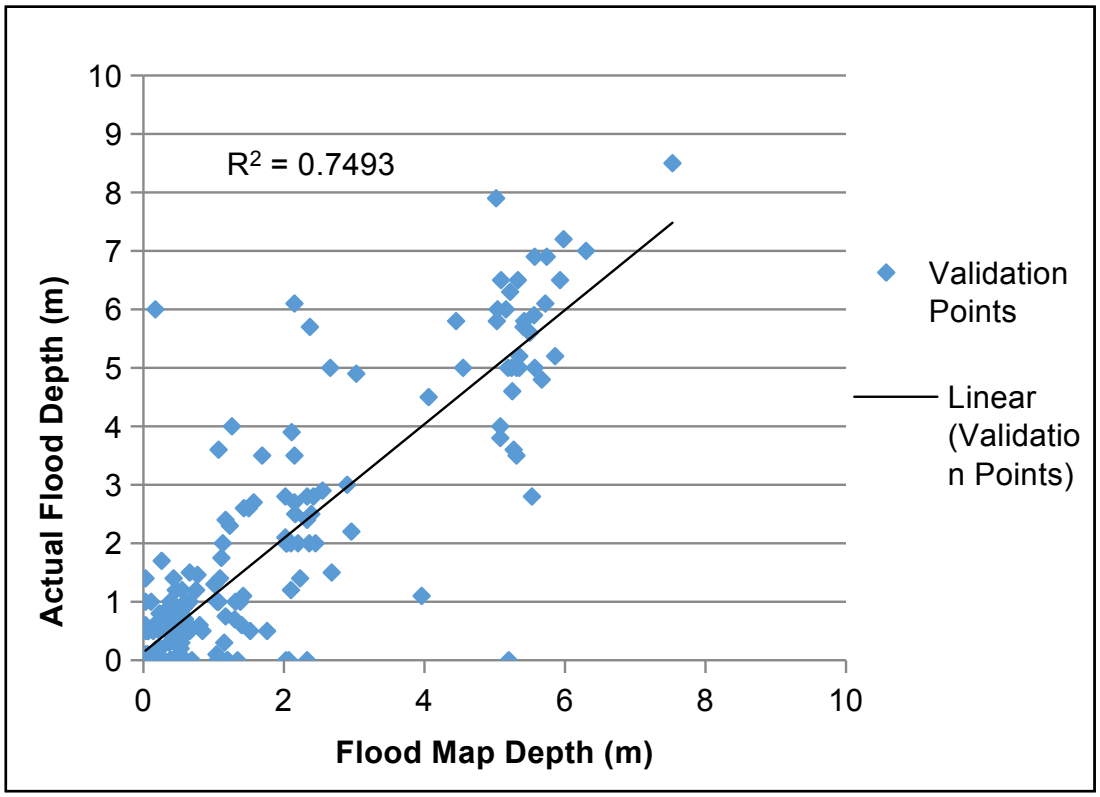


Figure 140. Flood Map Depth vs Actual Flood Depth

Table 90. Actual Flood Depth vs Simulated Flood Depth in Digos River Basin

DIGOS 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	21	14	9	8	3	1	56
	0.21-0.50	4	7	9	3	0	0	23
	0.51-1.00	4	13	12	7	0	0	36
	1.01-2.00	1	3	4	5	11	0	24
	2.01-5.00	0	0	0	8	17	12	37
	> 5.00	1	0	0	0	3	20	24
	Total	31	37	34	31	34	33	200

The overall accuracy generated by the flood model is estimated at 41.00%, with 82 points correctly matching the actual flood depths. In addition, there were 85 points estimated one level above and below the correct flood depths while there were 19 points and 14 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 77 points were overestimated while a total of 41 points were underestimated in the modelled flood depths of Digos.

Table 91. Summary of Accuracy Assessment in Digos River Basin Survey

	No. of Points	%
Correct	82	41.00
Overestimated	77	38.50
Underestimated	41	20.50
Total	200	100

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ANNEXES

Annex 1. Optech Technical Specifications of the Gemini Sensor

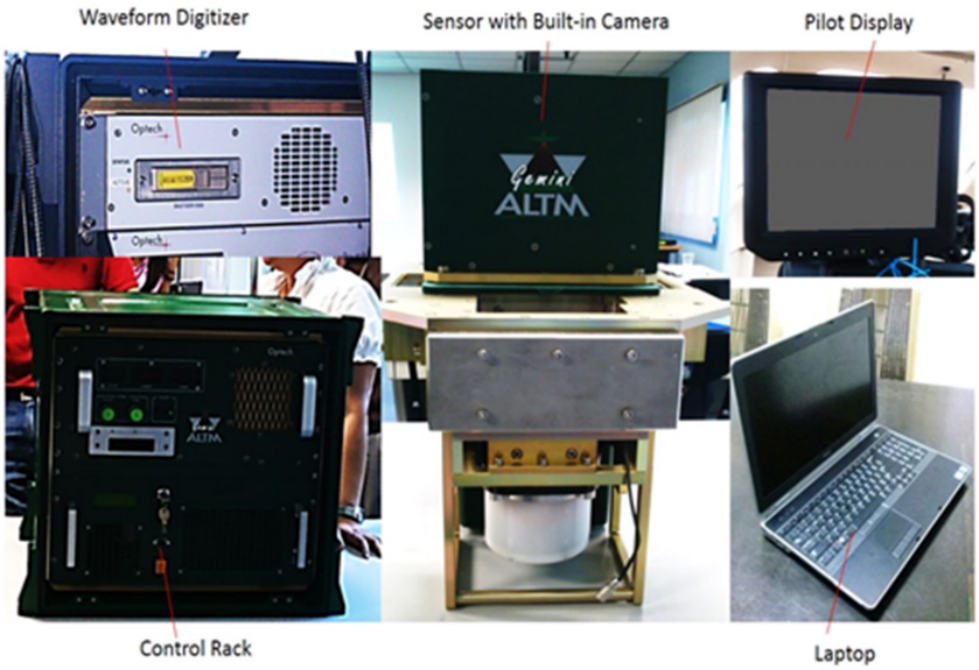


Figure A-1.1 Gemini Sensor

Table A-1.1 Parameters and Specifications of the Gemini Sensor

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

Annex 2. NAMRIA Certificates of Reference Points Used

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

August 08, 2014

CERTIFICATION

To whom it may concern:

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

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

Island: **MINDANAO**
Municipality: **PADADA**
Barangay: **NORTHERN PALIGUE**
MSL Elevation:

PRS92 Coordinates

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

WGS84 Coordinates

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

PTM / PRS92 Coordinates

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

UTM / PRS92 Coordinates

Northing: Easting: Zone:

Location Description

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

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

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

9908082014140602

CERTIFICATION INTERNATIONAL ISO 9001:2008 · AAB ACCREDITED QMS Certification Body Accreditation No. MSA-001
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 DVS-85

Annex 3. Baseling Processing Reports of Reference Points Used

Processing Summary

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

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

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

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

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

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

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

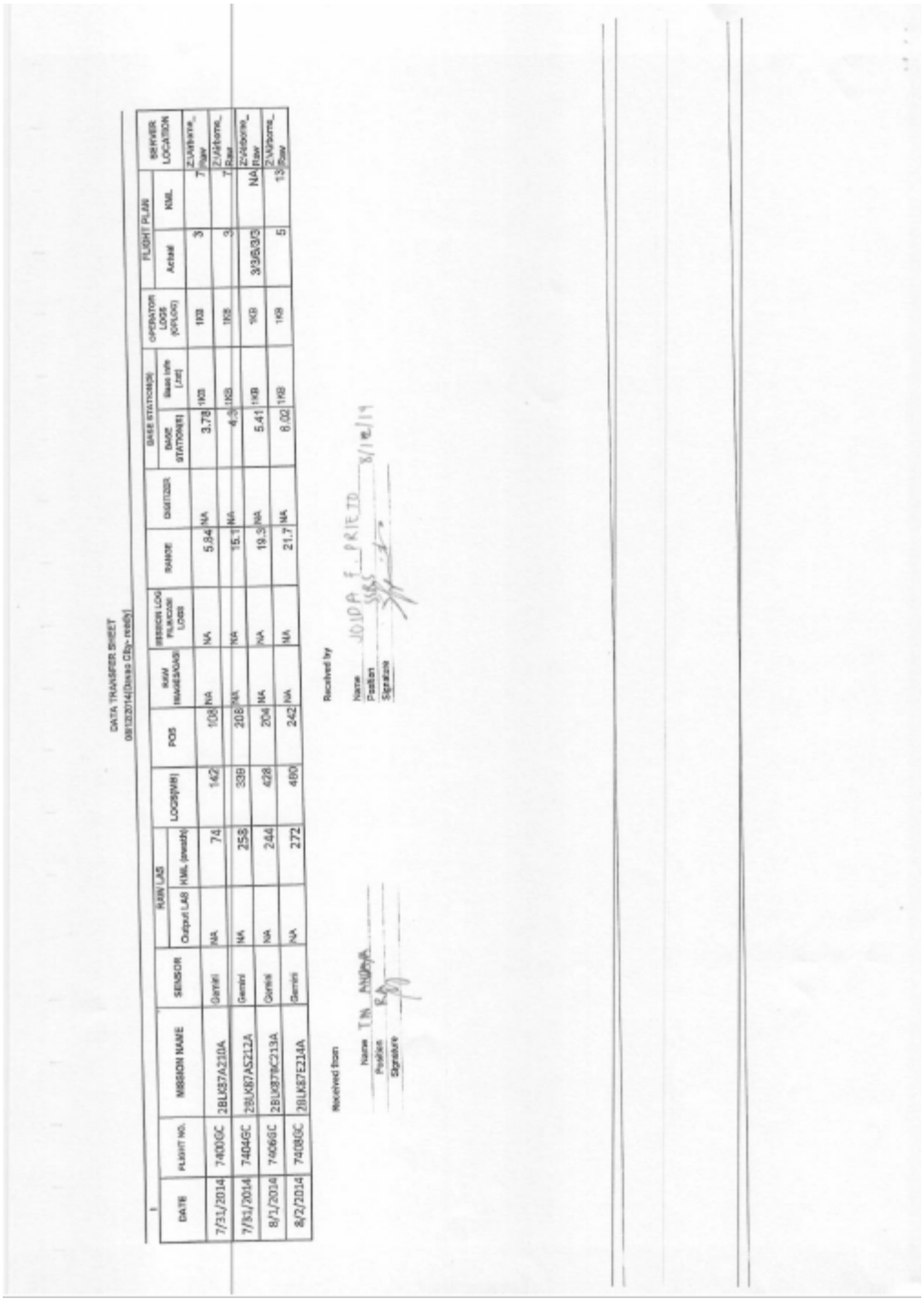
Figure A-3.1 BLLM-20

Annex 4. The LiDAR Survey Team

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	DESIGNATION	NAME	AGENCY / AFFILIATION
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LIDAR OPERATION	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
	Research Associate (RA)	FOR. MA. VERLINA TONGA	UP-TCAGP
	RA	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JERIEL PAUL ALAMBAN, GEOL	UP-TCAGP
LiDAR Operation	Airborne Security	TSG. MIKE DIAPANA	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JOHN BRYAN DONGUINES	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. NEIL ACHILLES AGAWIN	AAC

Annex 5. Data Transfer Sheet for Digos Floodplain



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

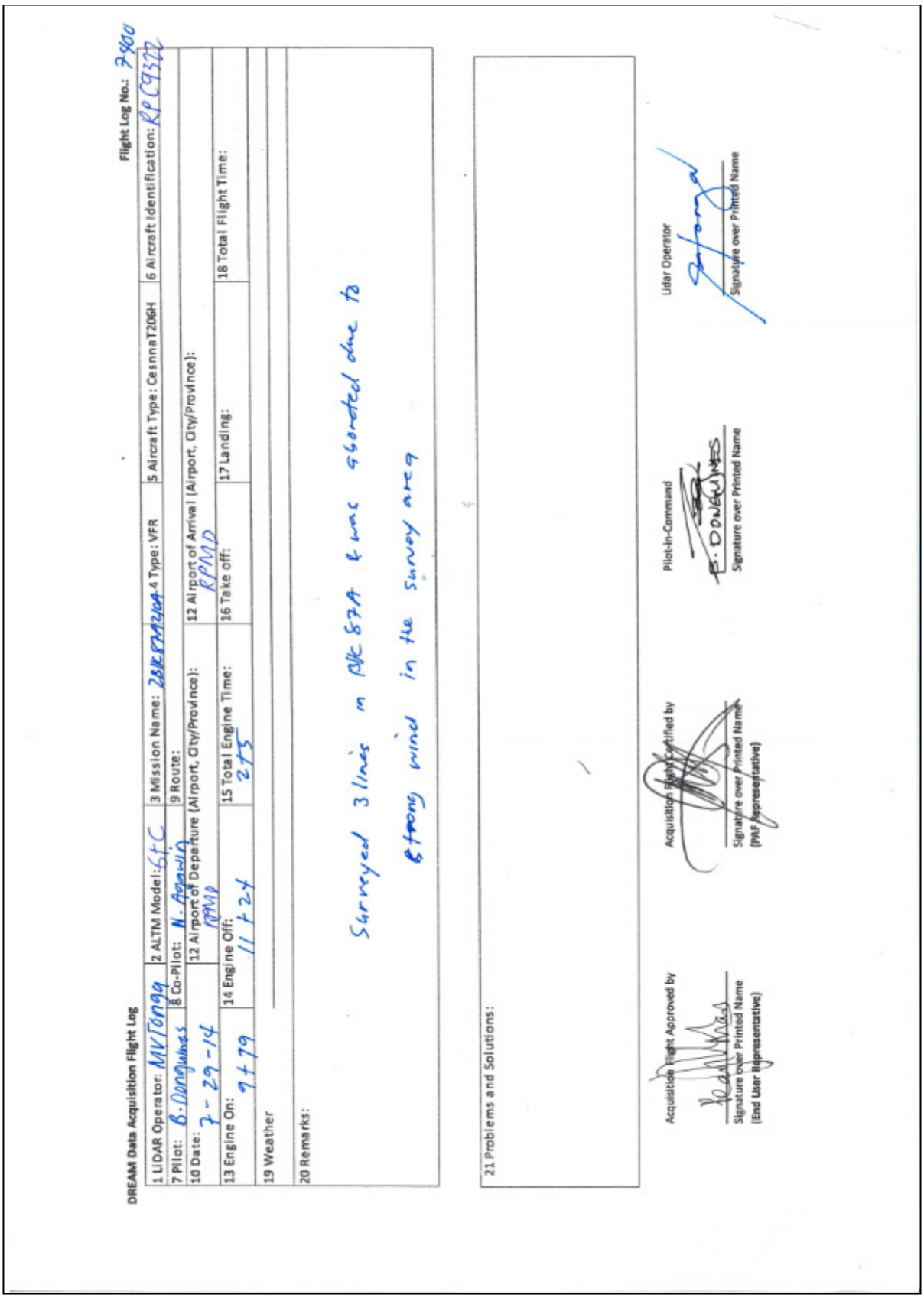
DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW/ LAS		LOGS(MB)	POS	RAW IMAGES(KB)	MISSION LOG FLIGHT LOGS	RANGE	DIGITIZER	GASE STATION(S)		OPERATOR LOGS (KPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (zipped)							BASE STATION(1)	Base Info (.txt)		Actual	KML	
7/31/2014	74010C	2BLK87A210A	Gemini	NA	74	142	108	NA	NA	5.84	NA	3.78	1KB	1KB	3	7	Z:\Airborne_Raw
7/31/2014	74045C	2BLK87AS212A	Gemini	NA	258	339	208	NA	NA	15.1	NA	4.8	1KB	1KB	3	7	Z:\Airborne_Raw
8/1/2014	74066C	2BLK87RC213A	Cessna	NA	244	428	204	NA	NA	19.3	NA	5.41	1KB	1KB	3/3/6/3/3	NA	Z:\Airborne_Raw
8/2/2014	74080C	2BLK87E214A	Gemini	NA	272	490	242	NA	NA	21.7	NA	6.02	1KB	1KB	5	13	Z:\Airborne_Raw

Received from
Name TIN ANDAYA
Position RA
Signature

Received by
Name JOJO A. PRIETO 8/12/14
Position SWS
Signature

Figure A-5.1. Data Transfer Sheet for Pulot Floodplain

Annex 6. Flight Logs



DREAM Data Acquisition Flight Log

Flight Log No.: 7400

1 LiDAR Operator: MV Tonga	2 ALTM Model: GTC	3 Mission Name: 23K[illegible] 4 Type: VFR	5 Aircraft Type: CessnaT206H	6 Aircraft Identification: RP C9370
7 Pilot: B. Dongallos	8 Co-Pilot: N. Arguelo	9 Route:		
10 Date: 7-29-24	11 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD	
13 Engine On: 9179	14 Engine Off: 11124	15 Total Engine Time: 2.5	16 Take off:	17 Landing:	18 Total Flight Time:

19 Weather

20 Remarks:

Surveyed 3 lines in A/C 67A & was aborted due to strong wind in the survey area

21 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

B. DONGALLOS
Signature over Printed Name

Lidar Operator

Signature over Printed Name

Figure A-6.1 Flight Log for 7400GC Mission

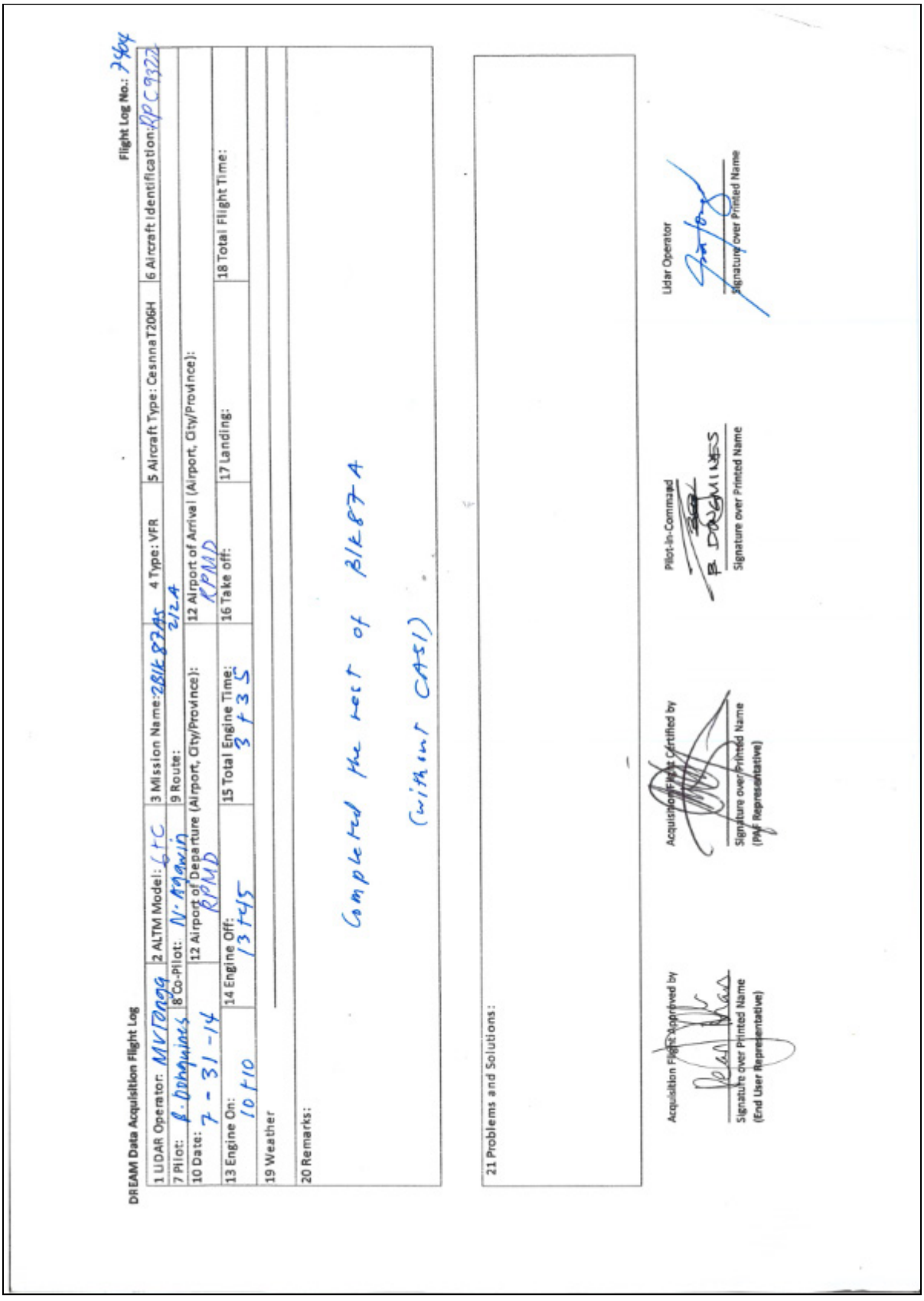
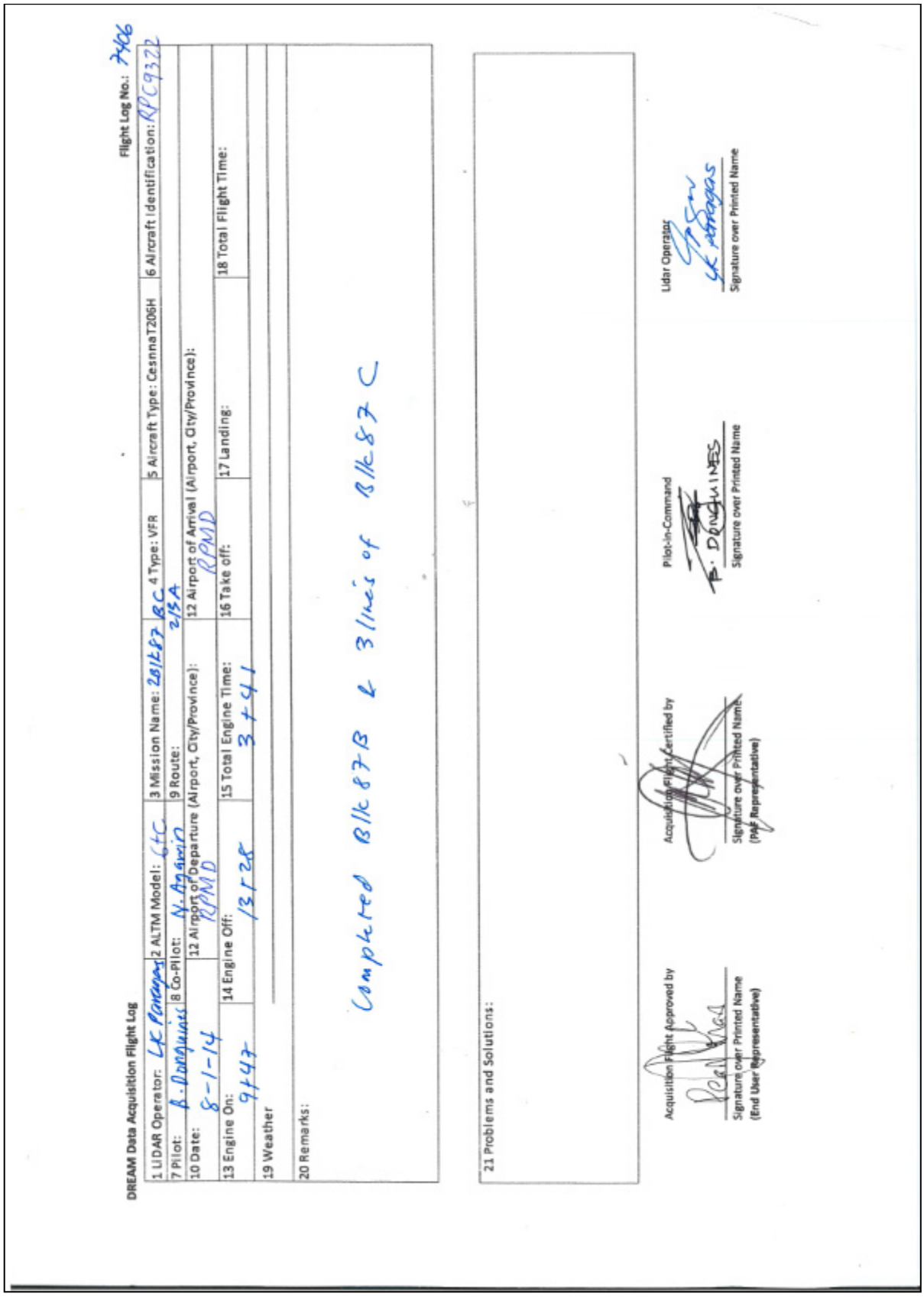


Figure A-6.2 Flight Log for 7404GC Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 7406

1 LIDAR Operator: Lic Romano	2 ALTM Model: GTC	3 Mission Name: 28KB7	4 Type: VFR	5 Aircraft Type: Cessna T206H
7 Pilot: A. Dongwines	8 Co-Pilot: N. Aquino	9 Route:		6 Aircraft Identification: RPC9322
10 Date: 8-1-14	11 Airport of Departure (Airport, City/Province): RPMD		12 Airport of Arrival (Airport, City/Province): RPMD	
13 Engine On: 9447	14 Engine Off: 12:28	15 Total Engine Time: 3+41	16 Take off:	17 Landing:
19 Weather				18 Total Flight Time:

20 Remarks:

Completed Blk 87B & 3 lines of Blk 87C

21 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name (End User Representative)

Acquisition Flight Certified by

Signature over Printed Name (PAF Representative)

Pilot-in-Command

Signature over Printed Name

Lidar Operator

Signature over Printed Name

Figure A-6.3 Flight Log for 7406GC Mission

Annex 7. Flight Status Report

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7400GC	BLK87A	2BLK87A210A	MV TONGA	July 29, 2014	Surveyed BLK87A (3 lines) then aborted the mission due to strong wind gustiness; flown without CASI @ 1000 AGL
7404GC	BLK87AS	2BLK87AS212A	MV TONGA	July 31, 2014	Completed the remaining lines of BLK87A (9 lines) without CASI @ 1000 AGL
7406GC	BLK87BC	2BLK87BC213A	LK PARAGAS	August 01, 2014	Surveyed BLK87B (9 lines) and BLK87C (4 lines) without CASI A @ 1000 AGL

LAS BOUNDARIES PER FLIGHT

Flight No. :	7400GC	
Area:	BLK87A	
Mission name:	2LK87A210A	
Parameters:	Altitude: 1000/900 m;	Scan Frequency: 50/40 Hz;
	Scan Angle: 20/25 deg;	Overlap: 30 %
Area covered:	48.522 km2	

Figure A-7.1. Swath Coverage of Flight No. 7400GC

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

Figure A-7.2. Swath Coverage of Flight No. 7404GC

Flight No. :	7406GC	
Area:	BLK87BC	
Mission name:	2BLK87BC213A	
Parameters:	Altitude: 1000 m;	Scan Frequency: 50 Hz;
	Scan Angle: 20 deg;	Overlap: 30 %
Area covered:	193.272 km2	

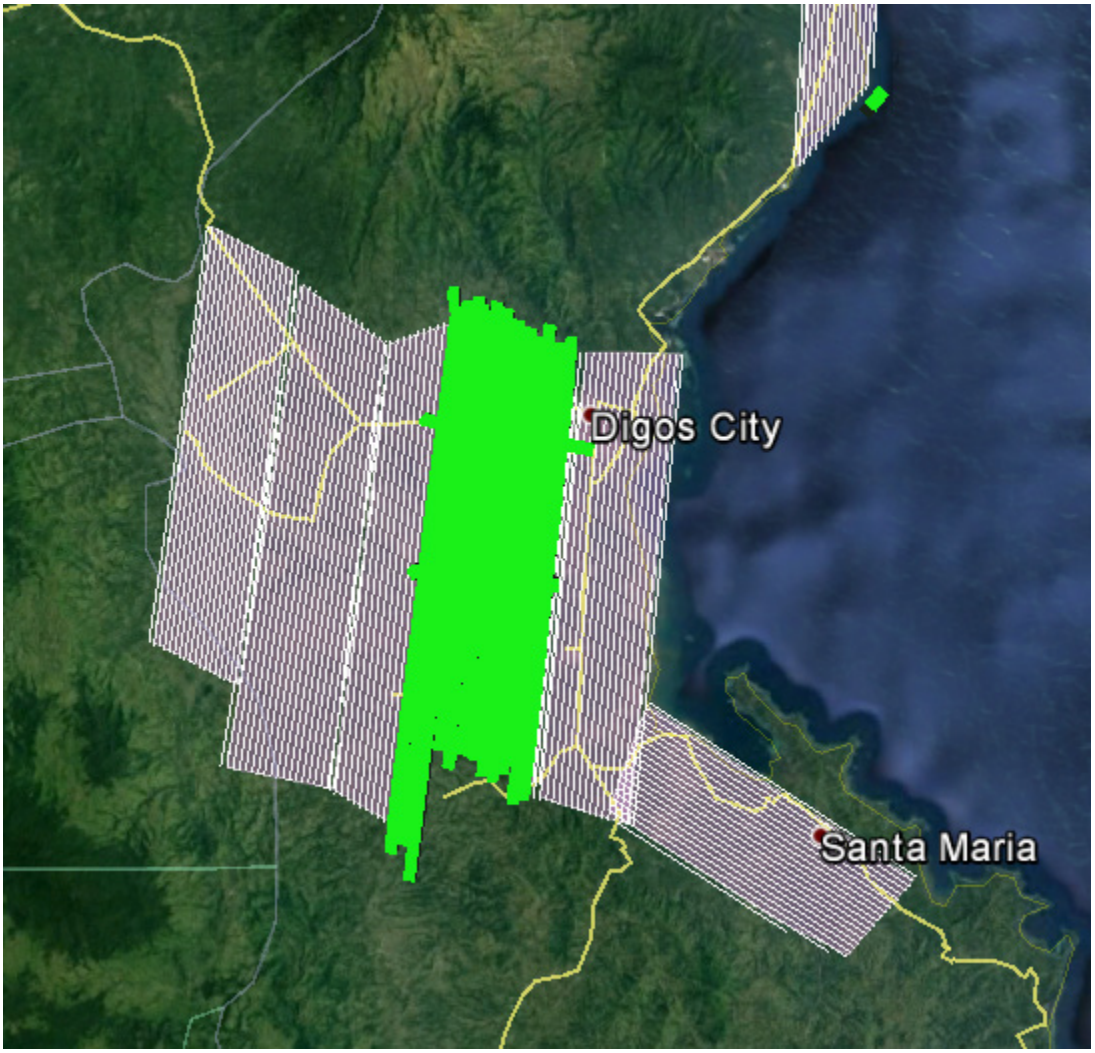


Figure A-7.3. Swath Coverage of Flight No. 7406GC

Annex 8. Digos Model Basin Parameters

Table A-8.1. Mission Summary Report for Mission Blk87A

Flight Area	Davao Oriental
Mission Name	Blk87A
Inclusive Flights	7400G, 7404G
Range data size	20.94 GB
POS	316 MB
Image	na
Base data size	8.08 MB
Transfer date	August 12, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	4.0
RMSE for East Position (<4.0 cm)	2.0
RMSE for Down Position (<8.0 cm)	12.0
Boresight correction stdev (<0.001deg)	0.000347
IMU attitude correction stdev (<0.001deg)	0.22618
GPS position stdev (<0.01m)	0.0104
Minimum % overlap (>25)	25.84%
Ave point cloud density per sq.m. (>2.0)	3.07
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	209
Maximum Height	565.04
Minimum Height	68.87
Classification (# of points)	
Ground	60085896
Low vegetation	64666486
Medium vegetation	97681467
High vegetation	217149246
Building	9552969
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Edgardo Gubatanga, Jr. Engr. Jeffrey Delica

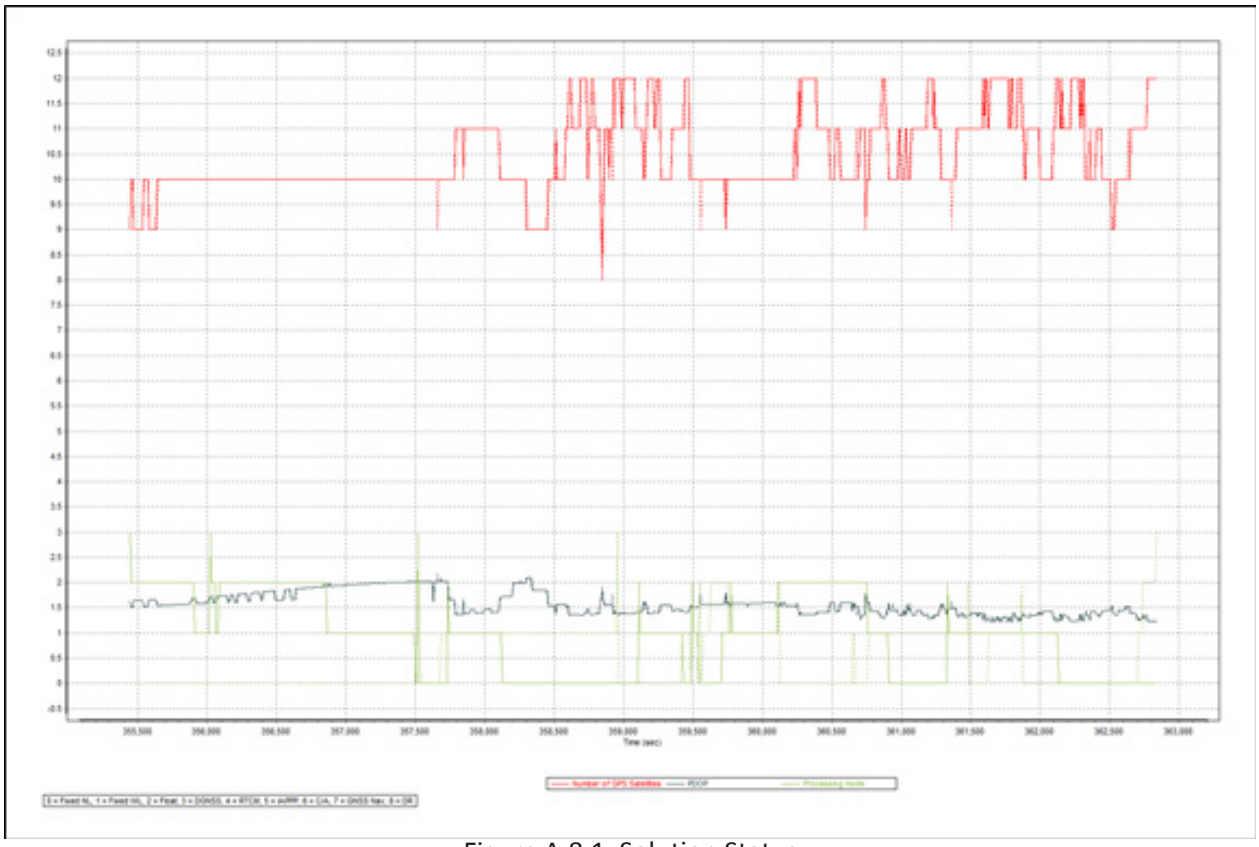


Figure A.8.1. Solution Status

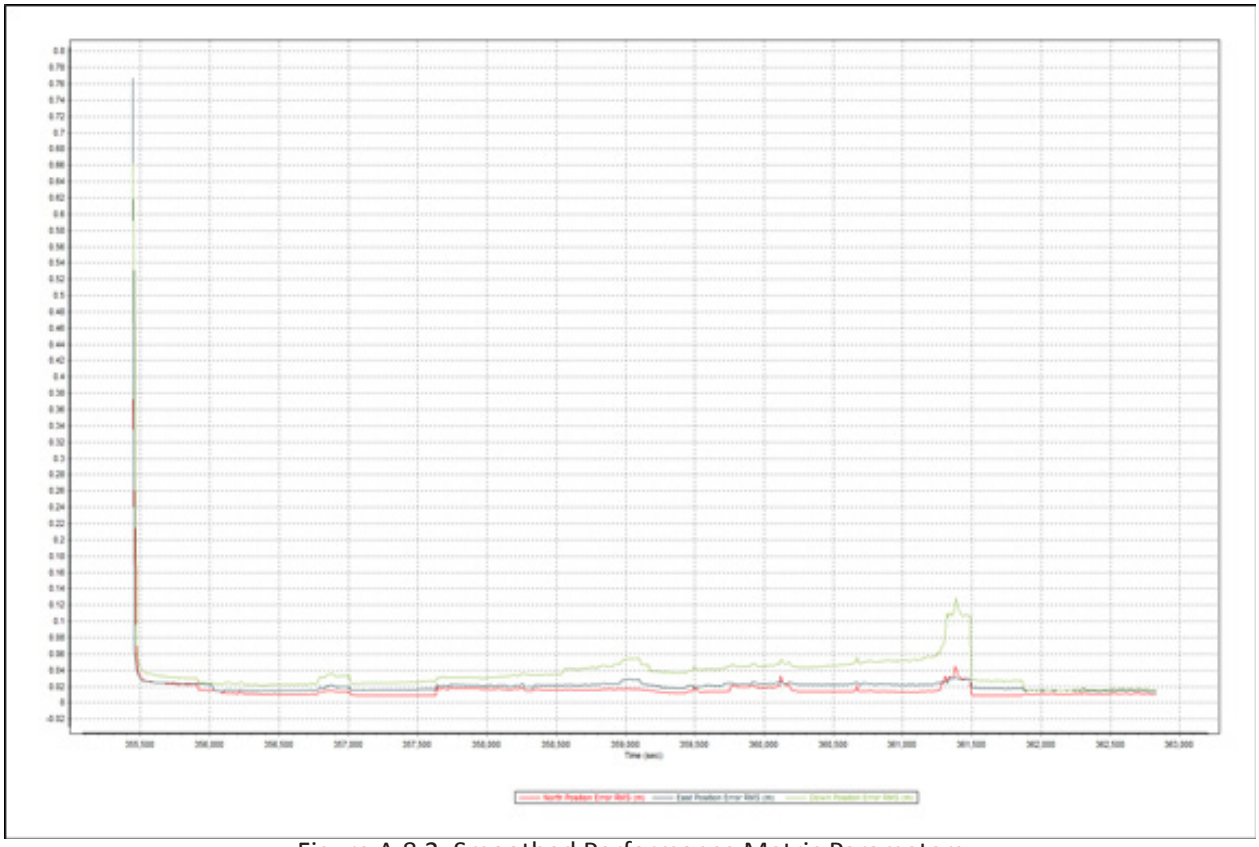


Figure A.8.2. Smoothed Performance Metric Parameters

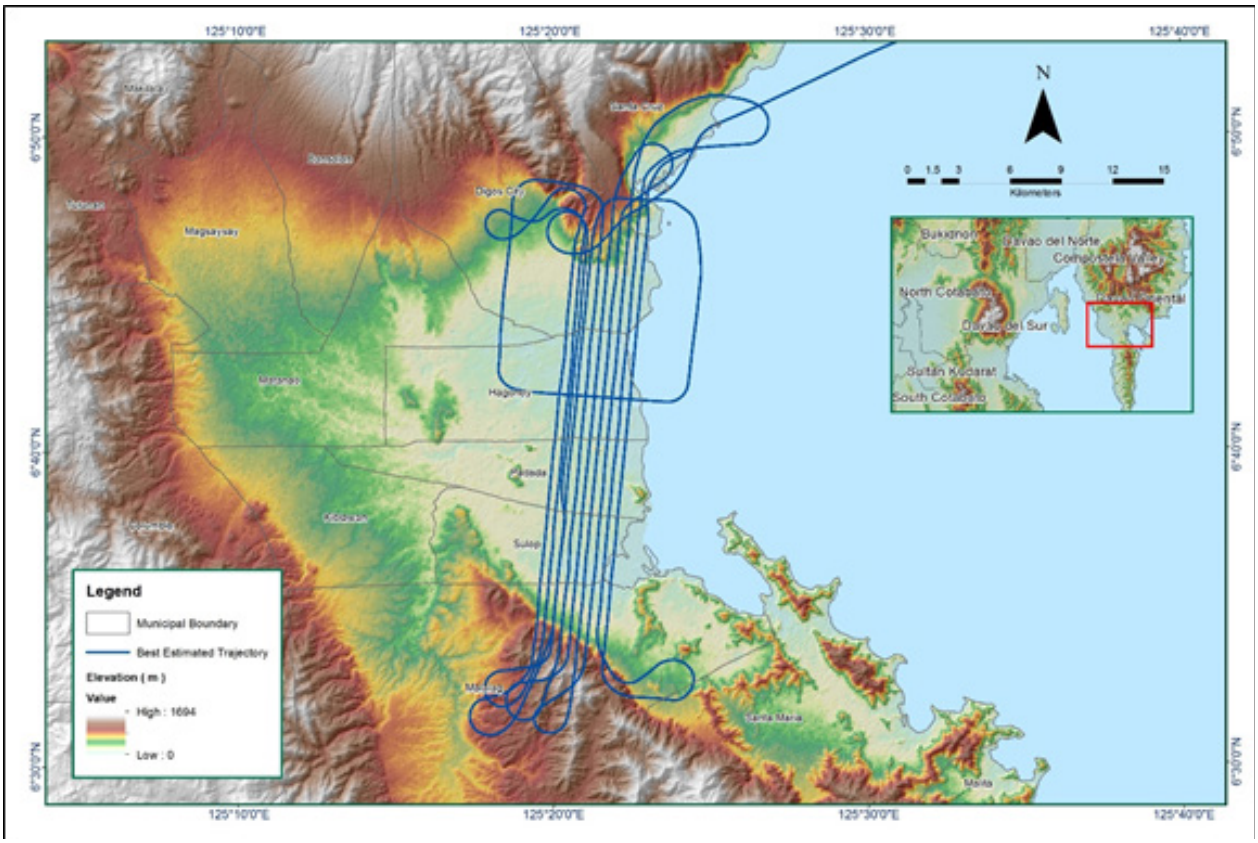


Figure A.8.3. Best Estimated Trajectory

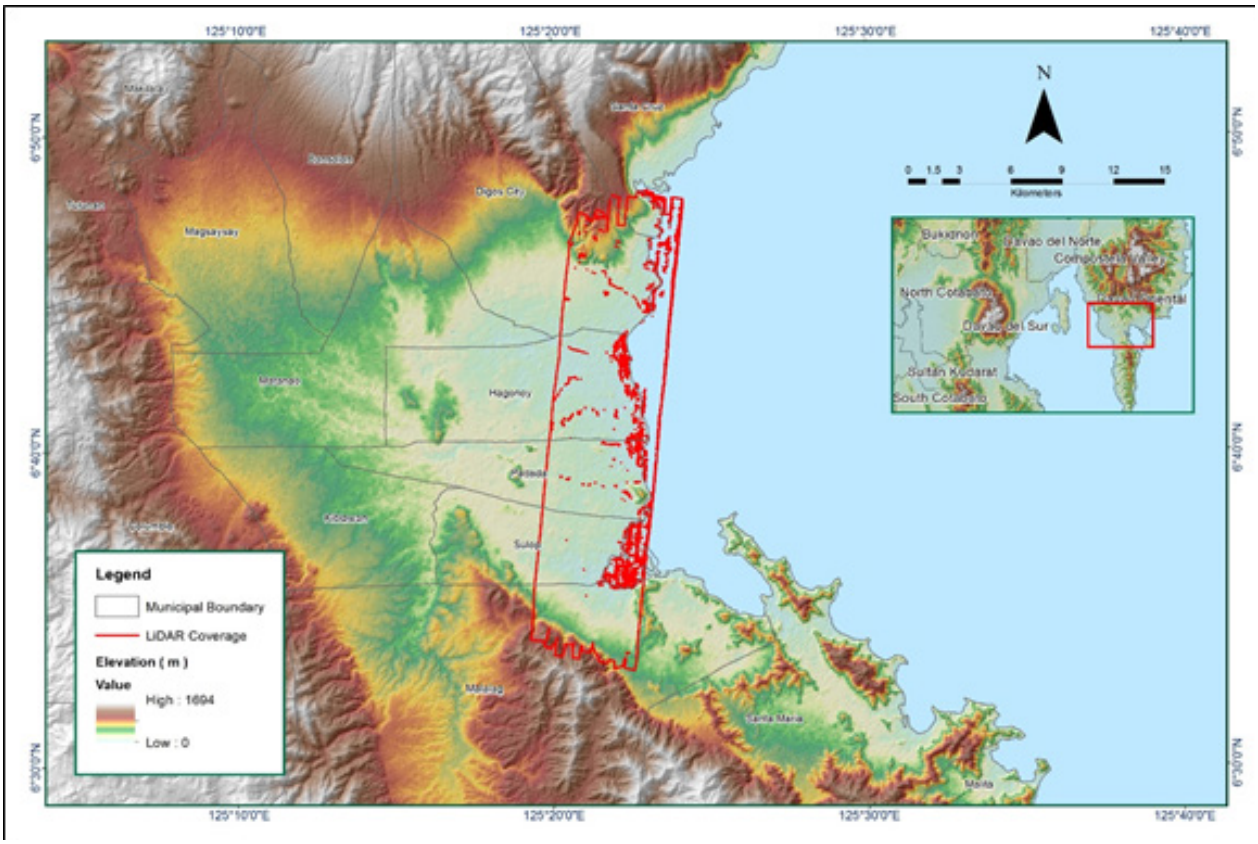


Figure A.8.4. Coverage of LiDAR data

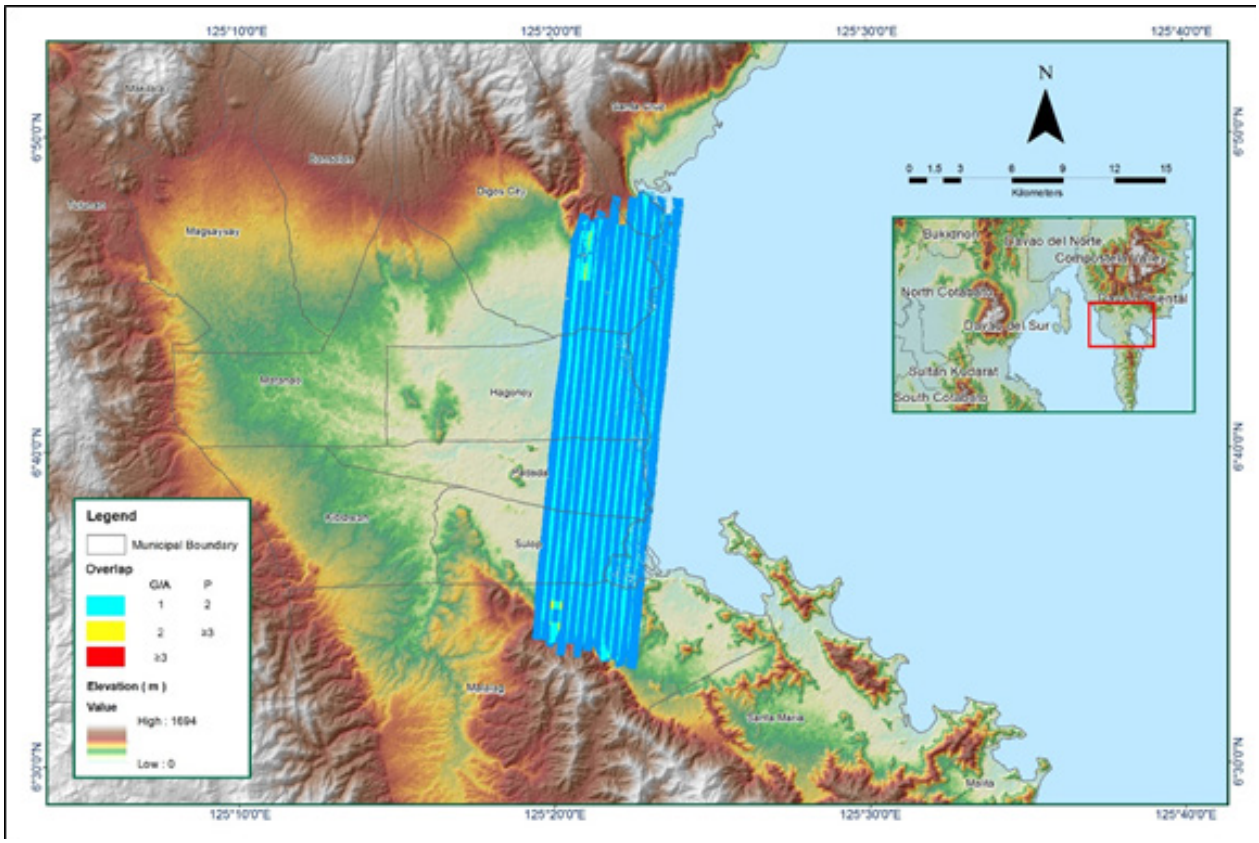


Figure A.8.5. Image of data overlap

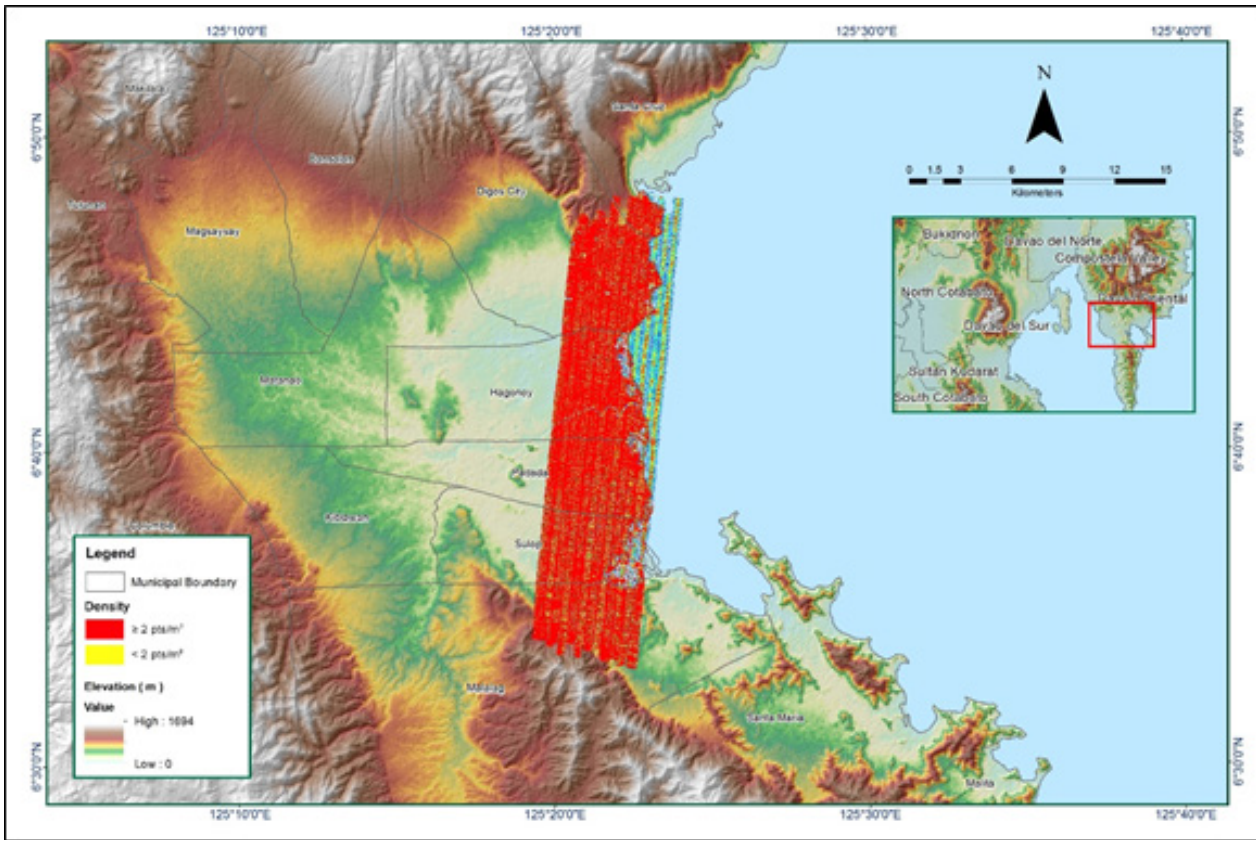


Figure A.8.6. Density map of merged LiDAR data

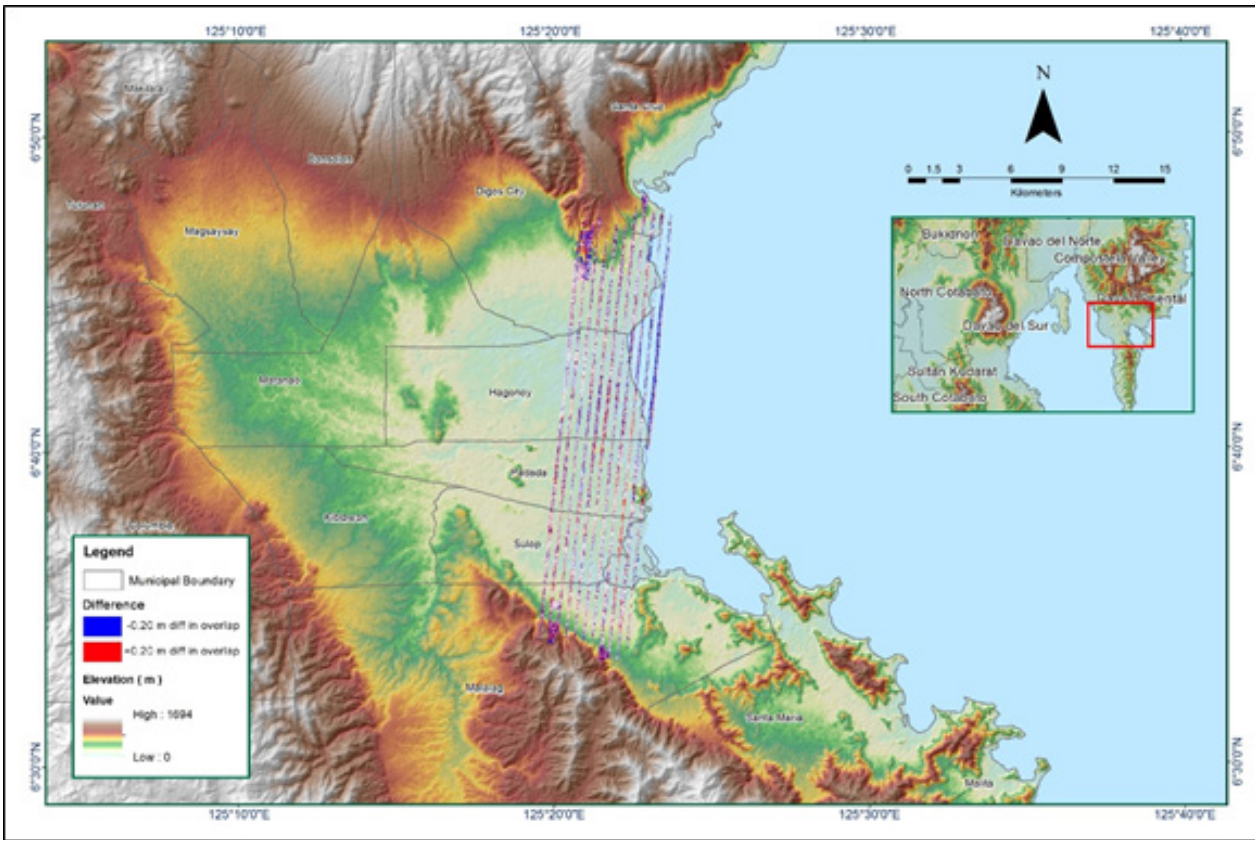


Figure A.8.7.Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk87B

Flight Area	Davao Oriental
Mission Name	Blk87B
Inclusive Flights	7406G
Range data size	19.3 GB
POS	204 MB
Image	na
Base data size	5.41
Transfer date	August 12, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.15
RMSE for East Position (<4.0 cm)	1.85
RMSE for Down Position (<8.0 cm)	3.4
Boresight correction stdev (<0.001deg)	0.000252
IMU attitude correction stdev (<0.001deg)	0.000532
GPS position stdev (<0.01m)	0.0017
Minimum % overlap (>25)	18.61%
Ave point cloud density per sq.m. (>2.0)	2.81
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	237
Maximum Height	450.25 m
Minimum Height	71.22 m
Classification (# of points)	
Ground	82393954
Low vegetation	95202868
Medium vegetation	138559665
High vegetation	184854717
Building	3481798
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. Gladys Mae Apat

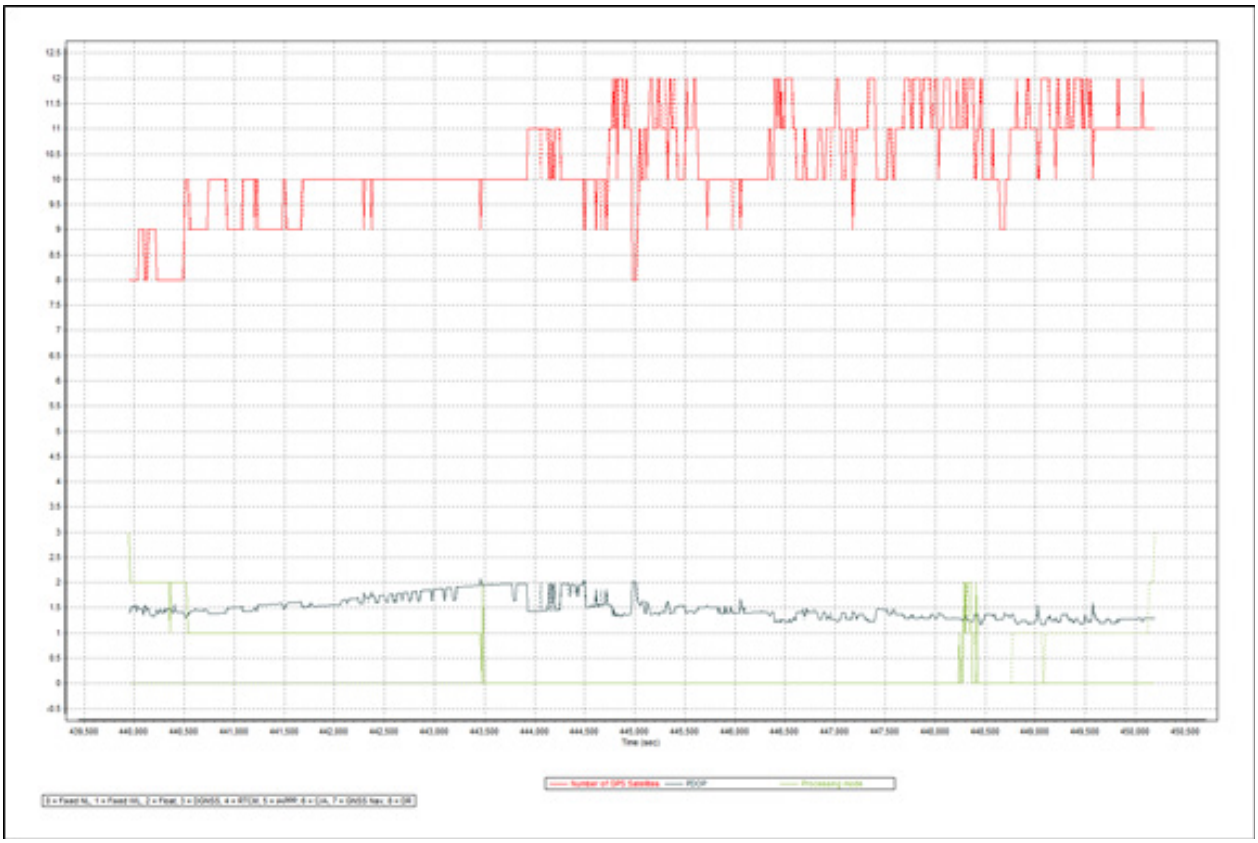


Figure A.8.8. Solution Status

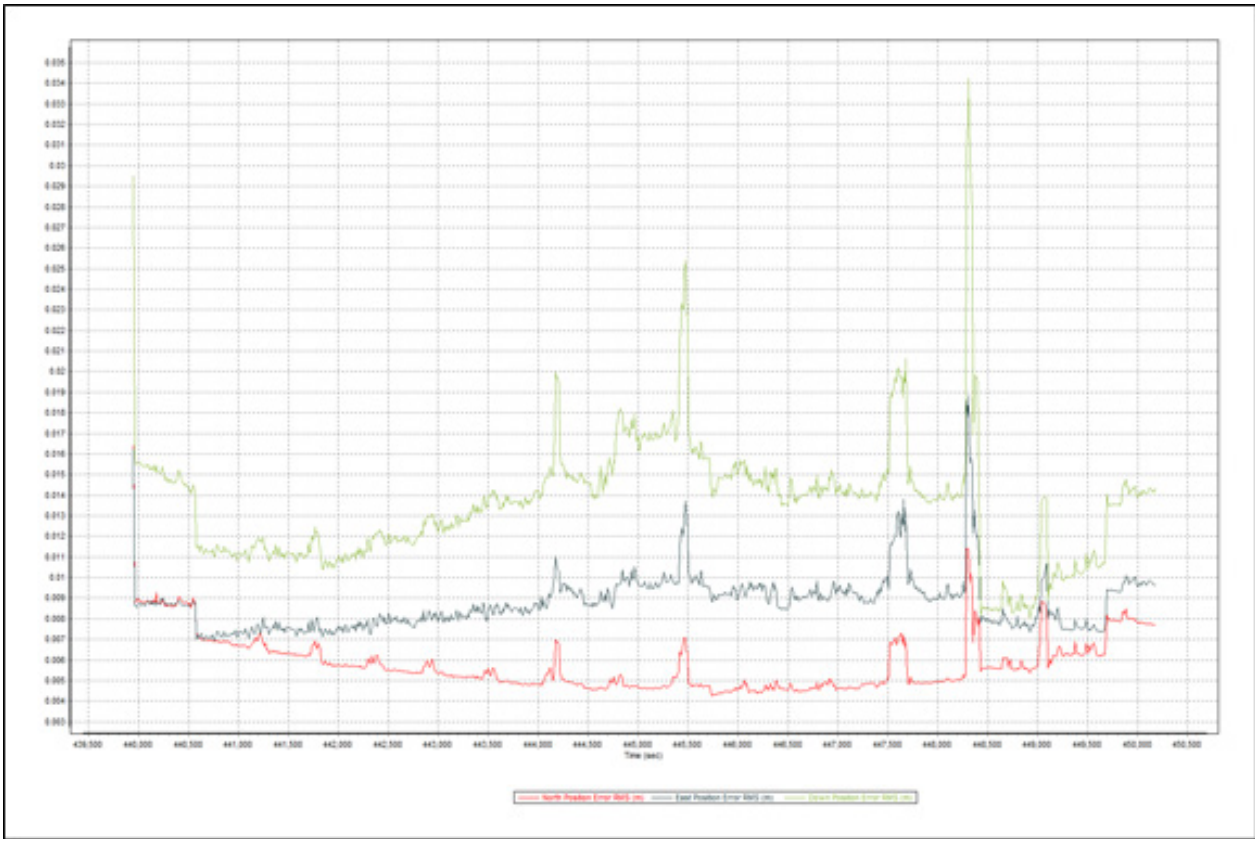


Figure A.8.9. Smoothed Performance Metric Parameters

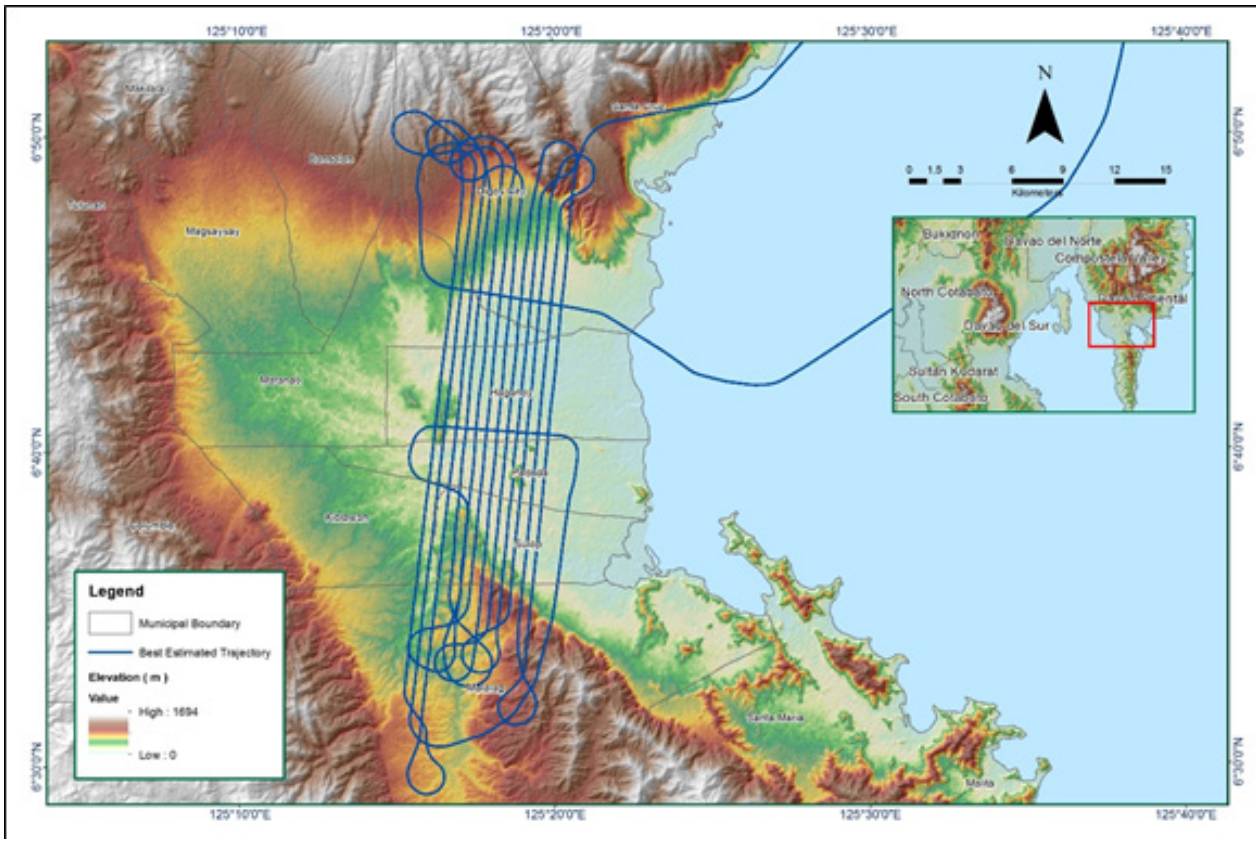


Figure A.8.10. Best Estimated Trajectory

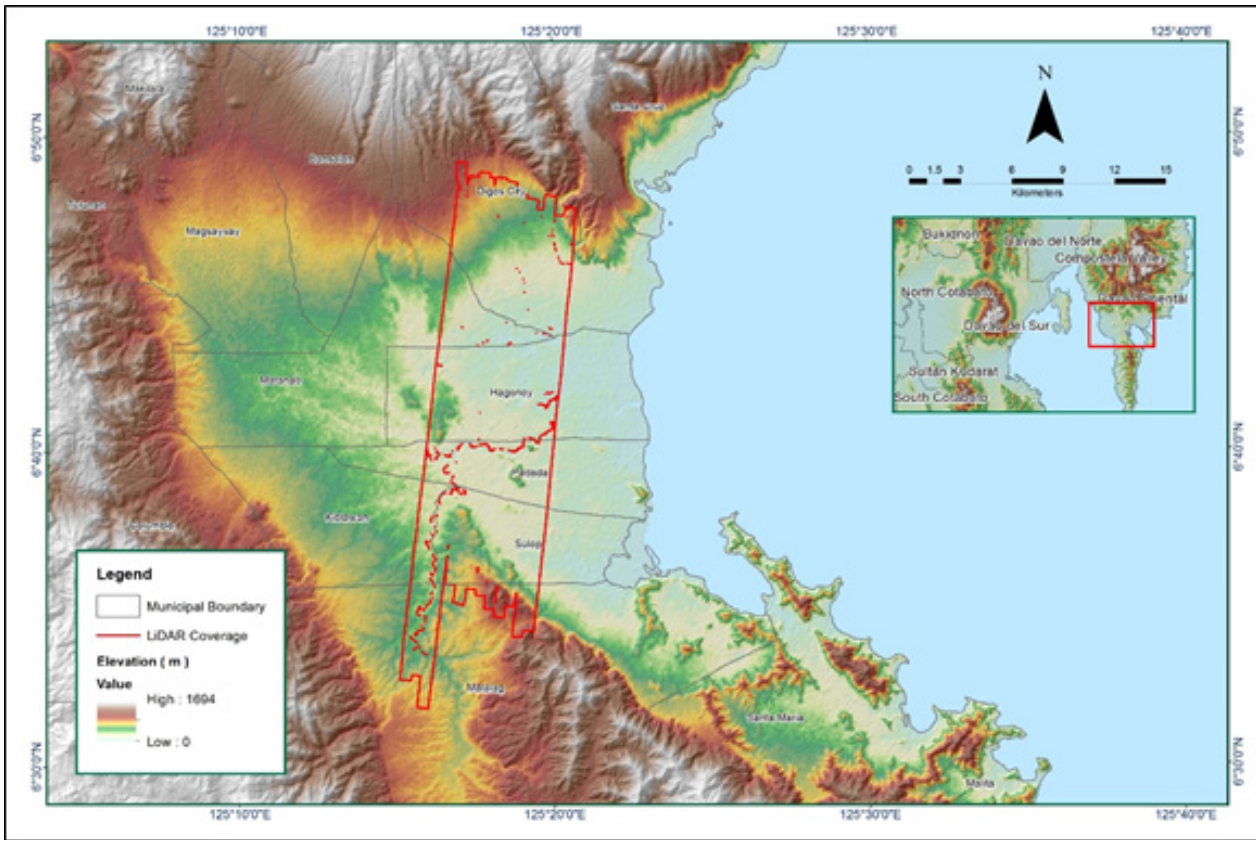


Figure A.8.11. Coverage of LiDAR data

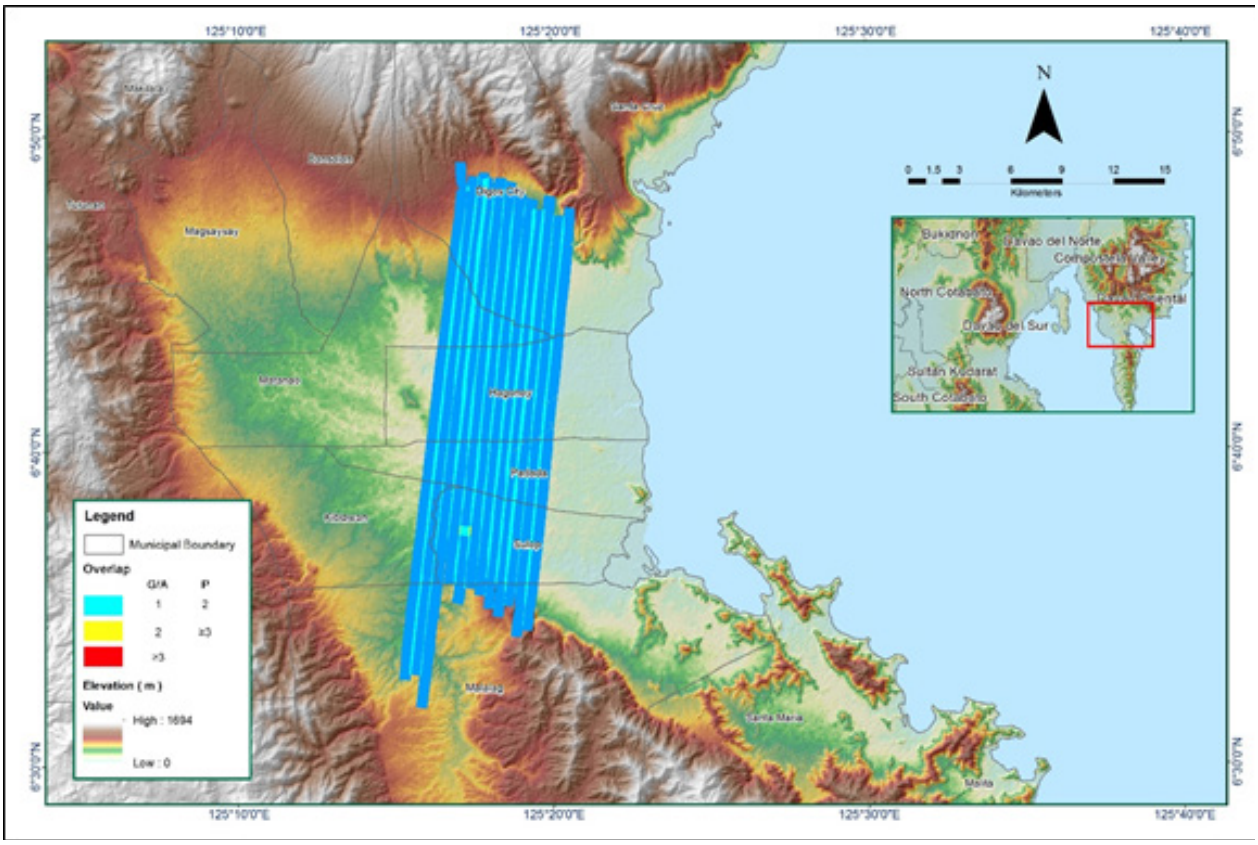


Figure A.8.12. Image of data overlap

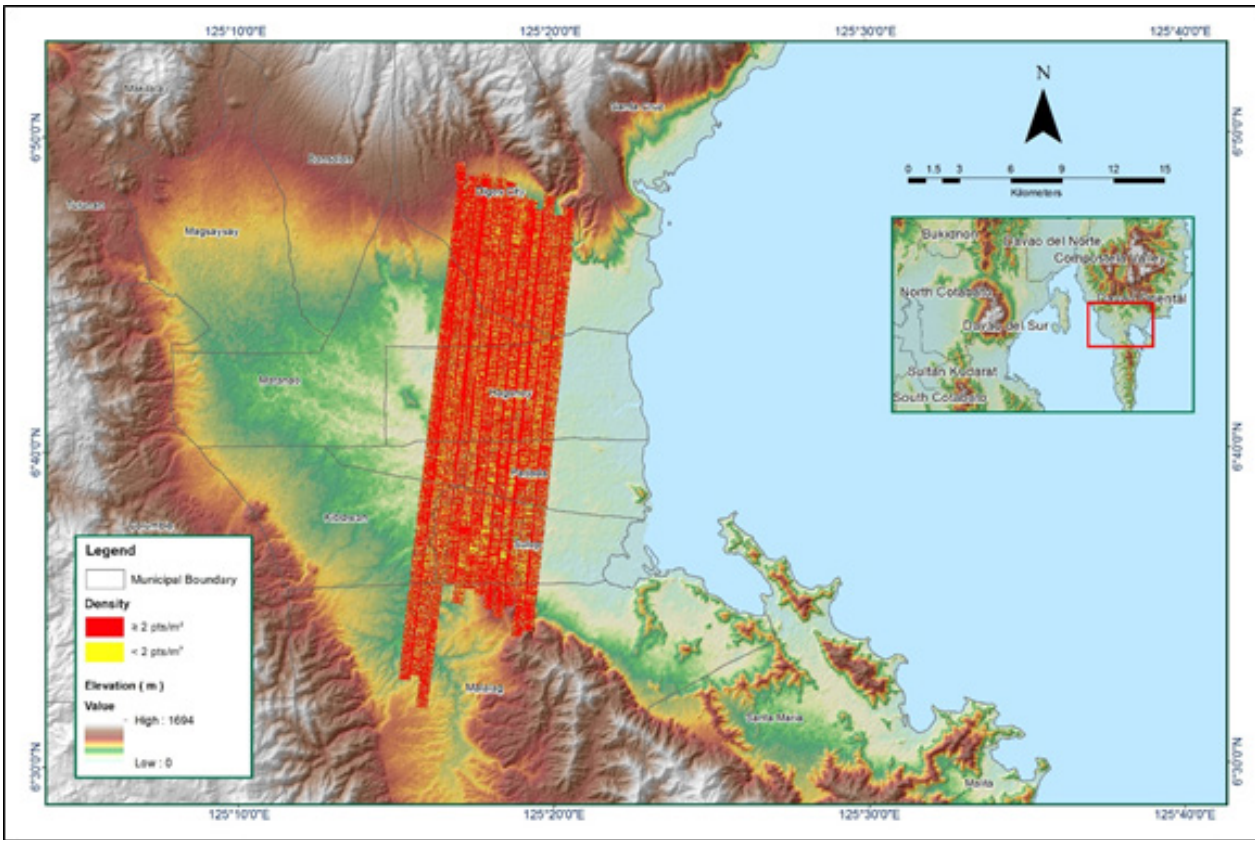


Figure A.8.13. Density map of merged LiDAR data

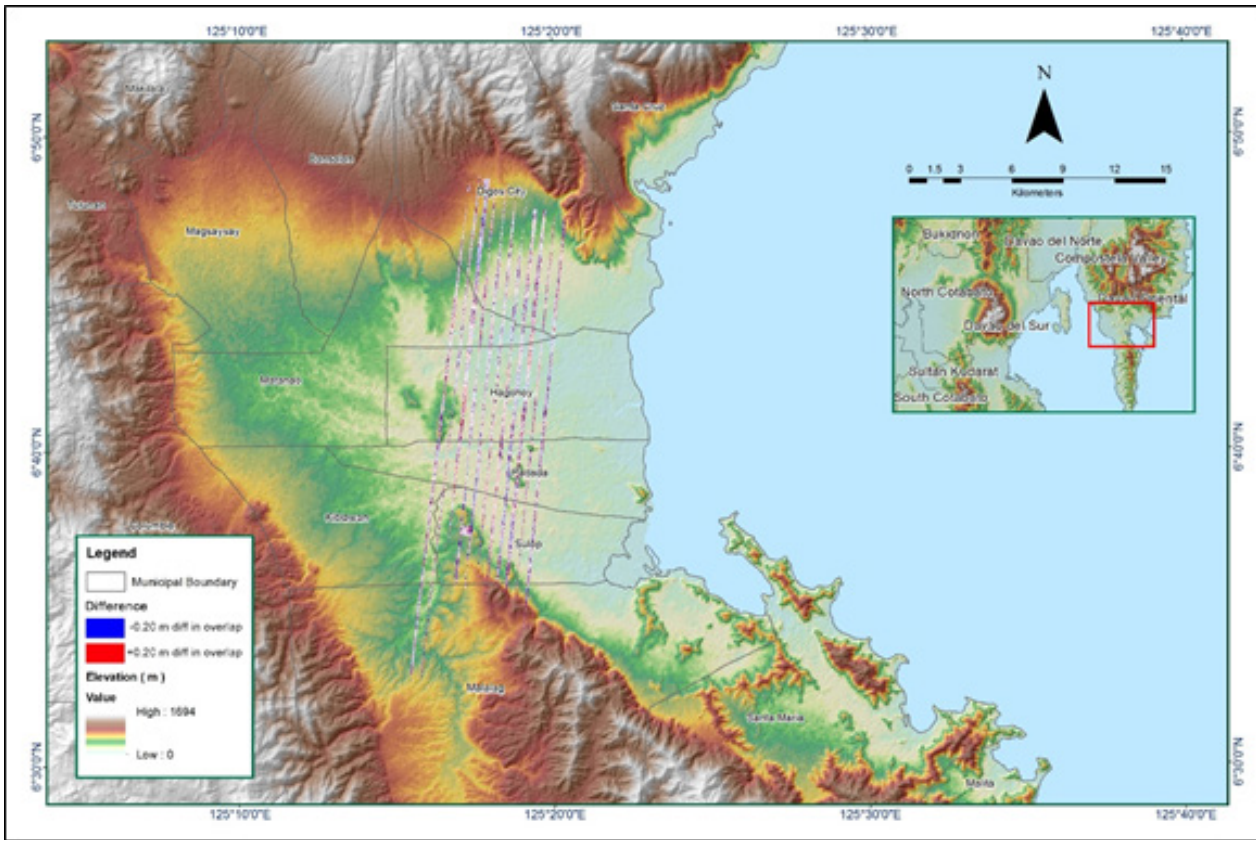


Figure A.8.14. Elevation difference between flight lines

Annex 9. Digos Model Basin Parameters

Table A-9.1. Digos Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W1000	19.7580	83.036	0.0	0.121340	0.666720	Discharge	0.0075890	0.266670	Ratio to Peak	0.150730
W1010	44.9970	54.454	0.0	0.264300	0.221710	Discharge	0.0056416	0.290370	Ratio to Peak	0.225000
W1020	14.7320	99.000	0.0	0.132740	0.492040	Discharge	0.0202213	0.441870	Ratio to Peak	0.150000
W1030	7.1090	37.395	0.0	0.133500	0.333680	Discharge	0.0034089	0.197530	Ratio to Peak	0.076667
W1040	8.4161	63.732	0.0	0.020000	0.029807	Discharge	0.0162580	0.290370	Ratio to Peak	0.113260
W1050	10.1260	62.844	0.0	0.060875	0.066455	Discharge	0.0065581	0.196530	Ratio to Peak	0.066667
W1060	13.2990	49.518	0.0	0.259600	0.629540	Discharge	0.0133218	0.659290	Ratio to Peak	0.100000
W1070	10.0760	67.956	0.0	0.081234	0.186050	Discharge	0.0017341	0.611780	Ratio to Peak	0.337500
W1080	12.4840	71.881	0.0	0.048557	0.079253	Discharge	0.0109150	0.400000	Ratio to Peak	0.100000
W1090	8.1138	50.478	0.0	0.031377	0.034308	Discharge	0.0060804	0.266670	Ratio to Peak	0.144060
W1100	7.6821	54.420	0.0	0.051936	0.332360	Discharge	0.0088894	0.529200	Ratio to Peak	0.096040
W1110	10.1380	89.074	0.0	0.114140	0.278360	Discharge	0.0014489	0.433380	Ratio to Peak	0.225000
W1120	12.6800	65.868	0.0	0.607630	0.444480	Discharge	0.0138128	0.636810	Ratio to Peak	0.098982
W1130	10.4940	53.687	0.0	0.115790	0.288690	Discharge	0.0002043	0.216970	Ratio to Peak	0.096672
W1140	6.9419	39.643	0.0	0.441700	2.148000	Discharge	0.0016469	0.426850	Ratio to Peak	0.150750
W1150	12.4240	60.158	0.0	0.243250	1.912800	Discharge	0.0060545	0.666670	Ratio to Peak	0.150750
W1160	1.5347	79.988	0.0	0.091551	0.339480	Discharge	0.0099392	0.666670	Ratio to Peak	0.147000
W1170	12.1330	49.971	0.0	0.120400	0.203050	Discharge	0.0126625	0.900000	Ratio to Peak	0.115550
W1180	13.4090	82.666	0.0	0.274920	0.296280	Discharge	0.0135634	0.653110	Ratio to Peak	0.101000
W1190	7.8528	75.520	0.0	0.076585	0.657000	Discharge	0.0013114	0.593090	Ratio to Peak	0.098490
W1200	2.2873	74.551	0.0	0.128160	0.360200	Discharge	0.0129281	0.666670	Ratio to Peak	0.099639
W1210	3.5762	84.888	0.0	0.080347	0.269560	Discharge	0.0061877	0.666670	Ratio to Peak	0.147000

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W790	17.1220	36.611	0.0	0.128820	0.209080	Discharge	0.0166686	1.000000	Ratio to Peak	0.100000
W800	18.4780	85.291	0.0	0.301500	0.331530	Discharge	0.0070897	1.000000	Ratio to Peak	0.337500
W810	20.5440	98.193	0.0	0.092050	0.150880	Discharge	0.0104047	1.000000	Ratio to Peak	0.150750
W820	19.0400	52.639	0.0	0.806790	0.876970	Discharge	0.0014010	1.000000	Ratio to Peak	0.225000
W830	4.8408	71.853	0.0	0.031113	0.050781	Discharge	0.0057315	1.000000	Ratio to Peak	0.100000
W840	14.7180	46.506	0.0	0.077338	0.098202	Discharge	0.0090784	1.000000	Ratio to Peak	0.100500
W850	16.9350	51.251	0.0	0.151180	0.364530	Discharge	0.0073777	1.000000	Ratio to Peak	0.337500
W860	22.8700	57.114	0.0	0.181210	0.593080	Discharge	0.0063660	1.000000	Ratio to Peak	0.150750
W870	18.1160	50.233	0.0	0.263160	0.429410	Discharge	0.0002290	1.000000	Ratio to Peak	0.100000
W880	18.6630	38.015	0.0	0.328530	0.533820	Discharge	0.0138101	1.000000	Ratio to Peak	0.100000
W890	18.5800	49.612	0.0	0.106990	0.260610	Discharge	0.0018135	1.000000	Ratio to Peak	0.100000
W900	15.7050	47.545	0.0	0.287410	1.042500	Discharge	0.0026212	1.000000	Ratio to Peak	0.100000
W910	9.8843	86.948	0.0	0.099988	0.541250	Discharge	0.0032801	1.000000	Ratio to Peak	0.226120
W920	17.0580	46.193	0.0	0.253510	0.613310	Discharge	0.0059076	1.000000	Ratio to Peak	0.150730
W930	6.2580	40.629	0.0	0.032583	0.079381	Discharge	0.0060737	1.000000	Ratio to Peak	0.100000
W940	7.3479	37.312	0.0	0.090684	0.760350	Discharge	0.0188718	1.000000	Ratio to Peak	0.060000
W950	20.6370	47.040	0.0	0.180490	0.294380	Discharge	0.0056754	1.000000	Ratio to Peak	0.100000
W960	12.2720	66.716	0.0	0.147310	0.262880	Discharge	0.0090929	1.000000	Ratio to Peak	0.100000
W970	9.9088	44.439	0.0	0.136050	0.062440	Discharge	0.0237426	1.000000	Ratio to Peak	0.226120
W980	18.7420	52.716	0.0	0.395820	0.433110	Discharge	0.0127690	1.000000	Ratio to Peak	0.100000
W990	9.9597	48.548	0.0	0.146630	0.367990	Discharge	0.0041090	0.882000	Ratio to Peak	0.151500
W1210	3.5762	84.888	0.0	0.080347	0.269560	Discharge	0.0061877	0.666670	Ratio to Peak	0.147000

Annex 10. Digos Model Reach Parameters

Table A-10.1. Digos Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	292.13	0.0914437	0.0715	Trapezoid	30	1
R110	Automatic Fixed Interval	122.43	0.0650542	0.0715	Trapezoid	30	1
R130	Automatic Fixed Interval	3057.10	0.0882039	0.0715	Trapezoid	30	1
R150	Automatic Fixed Interval	1016.70	0.1254200	0.0715	Trapezoid	30	1
R180	Automatic Fixed Interval	1222.50	0.0405024	0.0715	Trapezoid	30	1
R190	Automatic Fixed Interval	679.41	0.0072566	0.0715	Trapezoid	30	1
R220	Automatic Fixed Interval	3583.90	0.0495067	0.0715	Trapezoid	30	1
R250	Automatic Fixed Interval	1132.30	0.1560700	0.0715	Trapezoid	30	1
R290	Automatic Fixed Interval	2197.50	0.0953746	0.0715	Trapezoid	30	1
R300	Automatic Fixed Interval	88.28	0.2860700	0.0715	Trapezoid	30	1
R330	Automatic Fixed Interval	1671.00	0.0596151	0.0715	Trapezoid	30	1
R340	Automatic Fixed Interval	2273.40	0.0297879	0.0715	Trapezoid	30	1
R350	Automatic Fixed Interval	1166.70	0.0678957	0.0715	Trapezoid	30	1
R360	Automatic Fixed Interval	2207.20	0.1105000	0.0715	Trapezoid	30	1
R380	Automatic Fixed Interval	561.13	0.0828626	0.0715	Trapezoid	30	1
R390	Automatic Fixed Interval	1199.40	0.0508721	0.0715	Trapezoid	30	1
R410	Automatic Fixed Interval	805.98	0.1195700	0.0715	Trapezoid	30	1
R430	Automatic Fixed Interval	3112.90	0.0157194	0.0715	Trapezoid	30	1
R470	Automatic Fixed Interval	4595.80	0.0304907	0.0715	Trapezoid	30	1
R490	Automatic Fixed Interval	3110.50	0.0501535	0.0715	Trapezoid	30	1
R50	Automatic Fixed Interval	1698.50	0.0651042	0.0715	Trapezoid	30	1
R530	Automatic Fixed Interval	2031.40	0.0160842	0.0715	Trapezoid	30	1
R540	Automatic Fixed Interval	792.55	0.0156241	0.0715	Trapezoid	30	1

R550	Automatic Fixed Interval	325.56	0.0262925	0.0715	Trapezoid	30	1
R570	Automatic Fixed Interval	862.55	0.0163183	0.0715	Trapezoid	30	1
R580	Automatic Fixed Interval	2117.50	0.0206024	0.0715	Trapezoid	30	1
R600	Automatic Fixed Interval	2856.60	0.0229679	0.0715	Trapezoid	30	1
R610	Automatic Fixed Interval	1044.70	0.0144844	0.0715	Trapezoid	30	1
R630	Automatic Fixed Interval	1997.80	0.0177645	0.0715	Trapezoid	30	1
R640	Automatic Fixed Interval	2153.80	0.0131612	0.0715	Trapezoid	30	1
R650	Automatic Fixed Interval	1795.40	0.0111737	0.0715	Trapezoid	30	1
R670	Automatic Fixed Interval	5785.80	0.0029193	0.0715	Trapezoid	30	1
R690	Automatic Fixed Interval	1946.10	0.0010000	0.0715	Trapezoid	30	1
R70	Automatic Fixed Interval	1103.60	0.0503278	0.0715	Trapezoid	30	1

Annex 11. Digos Field Validation

Table A-11.1. Digos Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
1	6.742422	125.375991	0.03	1	0.97	Buhawi, Nov. 14, 2013	5-Year
2	6.748761	125.366839	0.03	0.5	0.47	Buhawi, Nov. 14, 2013	5-Year
3	6.752158	125.366060	0.03	0.6	0.57	Buhawi, Nov. 14, 2013	5-Year
4	6.749840	125.370642	0.03	1.4	1.37	Buhawi, Nov. 14, 2013	5-Year
5	6.742857	125.365253	0.05	0	-0.05	No Flood	5-Year
6	6.747413	125.356702	0.05	0.1	0.05	Buhawi, Nov. 14, 2013	5-Year
7	6.740694	125.363009	0.05	0	-0.05	No Flood	5-Year
8	6.745326	125.371829	0.07	0.5	0.43	Buhawi, Nov. 14, 2013	5-Year
9	6.747161	125.361370	0.11	1	0.89	Bagyong Titang	5-Year
10	6.751964	125.368566	0.14	0.5	0.36	Buhawi, Nov. 14, 2013	5-Year
11	6.740242	125.369495	0.14	0	-0.14	No Flood	5-Year
12	6.743355	125.357199	0.19	0.2	0.01	Buhawi, Nov. 14, 2013	5-Year
13	6.745873	125.375933	0.19	0.64	0.45	Buhawi, Nov. 14, 2013	5-Year
14	6.739186	125.373252	0.22	0	-0.22	No Flood	5-Year
15	6.742902	125.371297	0.24	0.2	-0.04	Buhawi, Nov. 14, 2013	5-Year
16	6.739449	125.366112	0.24	0	-0.24	No Flood	5-Year
17	6.744472	125.376794	0.28	0.8	0.52	Buhawi, Nov. 14, 2013	5-Year
18	6.742652	125.378382	0.28	0.8	0.52	Buhawi, Nov. 14, 2013	5-Year
19	6.738414	125.381932	0.35	0.7	0.35	Buhawi, Nov. 14, 2013	5-Year
20	6.746582	125.370029	0.36	0.8	0.44	Buhawi, Nov. 14, 2013	5-Year
21	6.740972	125.378772	0.37	0.3	-0.07	Buhawi, Nov. 14, 2013	5-Year
22	6.746142	125.372920	0.38	0.89	0.51	Buhawi, Nov. 14, 2013	5-Year
23	6.737282	125.377126	0.4	0.8	0.40	Buhawi, Nov. 14, 2013	5-Year
24	6.735561	125.375510	0.4	0.5	0.10	Buhawi, Nov. 14, 2013	5-Year
25	6.738826	125.384281	0.41	0.95	0.54	Buhawi, Nov. 14, 2013	5-Year
26	6.738798	125.375253	0.43	0.5	0.07	Buhawi, Nov. 14, 2013	5-Year
27	6.749413	125.369422	0.43	1.4	0.97	Buhawi, Nov. 14, 2013	5-Year
28	6.735335	125.379212	0.44	0.95	0.51	Buhawi, Nov. 14, 2013	5-Year
29	6.737509	125.379115	0.46	0.6	0.14	Buhawi, Nov. 14, 2013	5-Year
30	6.748136	125.369959	0.46	1.2	0.74	Buhawi, Nov. 14, 2013	5-Year
31	6.741822	125.373007	0.47	0.8	0.33	Buhawi, Nov. 14, 2013	5-Year
32	6.754218	125.367419	0.47	0.5	0.03	Buhawi, Nov. 14, 2013	5-Year
33	6.738540	125.376579	0.55	0.75	0.20	Buhawi, Nov. 14, 2013	5-Year
34	6.744374	125.380888	0.58	0.9	0.32	Buhawi, Nov. 14, 2013	5-Year
35	6.750359	125.364168	0.6	0	-0.60	No Flood	5-Year
36	6.747394	125.371428	0.61	0.62	0.01	Buhawi, Nov. 14, 2013	5-Year
37	6.734686	125.377186	1.11	1.75	0.64	Buhawi, Nov. 14, 2013	5-Year
38	6.753242	125.368870	2.02	2.8	0.78	Buhawi, Nov. 14, 2013	5-Year
39	6.752930	125.366696	2.02	2.1	0.08	Buhawi, Nov. 14, 2013	5-Year
40	6.751781	125.370152	2.04	2	-0.04	Buhawi, Nov. 14, 2013	5-Year
41	6.741495	125.379927	2.04	2	-0.04	Buhawi, Nov. 14, 2013	5-Year
42	6.749766	125.372852	2.39	2.5	0.11	Buhawi, Nov. 14, 2013	5-Year
43	6.749152	125.374967	3.96	1.1	-2.86	Buhawi, Nov. 14, 2013	5-Year
44	6.755575	125.384819	0.11	0	-0.11	No Flood	5-Year
45	6.756354	125.388818	0.18	0	-0.18	No Flood	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
46	6.752874	125.386519	0.22	0.6	0.38	Buhawi, Nov. 14, 2013	5-Year
47	6.753286	125.388243	0.23	0.5	0.27	Sealevel rise	5-Year
48	6.757200	125.383105	0.26	0	-0.26	No Flood	5-Year
49	6.756540	125.383920	0.38	0	-0.38	No Flood	5-Year
50	6.756531	125.373813	0.51	0.5	-0.01	Buhawi, Nov. 14, 2013	5-Year
51	6.755233	125.387152	0.59	0.7	0.11	Buhawi, Nov. 14, 2013	5-Year
52	6.755740	125.372524	0.54	0.3	-0.24	Buhawi, Nov. 14, 2013	5-Year
53	6.750157	125.382573	0.55	1.2	0.65	Buhawi, Nov. 14, 2013	5-Year
54	6.750600	125.384977	0.56	0.9	0.34	Buhawi, Nov. 14, 2013	5-Year
55	6.758093	125.389262	0.57	0	-0.57	No Flood	5-Year
56	6.754496	125.387696	0.59	0.7	0.11	Buhawi, Nov. 14, 2013	5-Year
57	6.748210	125.381821	0.6	1	0.40	Buhawi, Nov. 14, 2013	5-Year
58	6.758897	125.387185	0.64	0.6	-0.04	Buhawi, Nov. 14, 2013	5-Year
59	6.756807	125.370047	0.66	1	0.34	Buhawi, Nov. 14, 2013	5-Year
60	6.748824	125.384623	0.66	1.5	0.84	Buhawi, Nov. 14, 2013	5-Year
61	6.751523	125.385892	0.75	1.2	0.45	Buhawi, Nov. 14, 2013	5-Year
62	6.753706	125.373220	0.77	1.46	0.69	Buhawi, Nov. 14, 2013	5-Year
63	6.738844	125.352316	0.04	0	-0.04	No Flood	5-Year
64	6.738514	125.358903	0.11	0	-0.11	No Flood	5-Year
65	6.732786	125.360540	0.16	0	-0.16	No Flood	5-Year
66	6.733292	125.374216	0.38	1	0.62	Buhawi, Nov. 14, 2013	5-Year
67	6.734080	125.377038	0.8	0.6	-0.20	2Buhawi, Nov. 14, 2013	5-Year
68	6.733833	125.375762	1.01	1.3	0.29	Buhawi, Nov. 14, 2013	5-Year
69	6.729537	125.373580	1.05	0	-1.05	No Flood	5-Year
70	6.730773	125.374107	1.11	0	-1.11	No Flood	5-Year
71	6.779884	125.331562	2.45	2	-0.45	Buhawi, Nov. 14, 2013	5-Year
72	6.743658	125.351483	0.14	0	-0.14	No Flood	5-Year
73	6.760811	125.362517	0.51	0	-0.51	No Flood	5-Year
74	6.759553	125.366394	0.51	0.3	-0.21	Yolanda, Nov. 7, 2013	5-Year
75	6.761426	125.364400	0.64	0.5	-0.14	Buhawi, Nov. 14, 2013	5-Year
76	6.762487	125.360542	1.09	1.4	0.31	Buhawi, Nov. 14, 2013	5-Year
77	6.761234	125.361643	4.45	5.8	1.35	Buhawi, Nov. 14, 2013	5-Year
78	6.758775	125.364245	5.56	5.9	0.34	Buhawi, Nov. 14, 2013	5-Year
79	6.759689	125.363058	5.57	5	-0.57	Buhawi, Nov. 14, 2013	5-Year
80	6.757638	125.340214	0.38	0	-0.38	No Flood	5-Year
81	6.763430	125.339608	0.03	0	-0.03	No Flood	5-Year
82	6.771970	125.336881	0.46	0.3	-0.16	Buhawi, Nov. 14, 2013	5-Year
83	6.769632	125.336755	0.5	0.1	-0.40	Buhawi, Nov. 14, 2013	5-Year
84	6.771423	125.338626	0.53	0.2	-0.33	Buhawi, Nov. 14, 2013	5-Year
85	6.774788	125.337101	0.54	0.8	0.26	Buhawi, Nov. 14, 2013	5-Year
86	6.778863	125.335554	0.56	0	-0.56	No Flood	5-Year
87	6.777274	125.337763	0.84	0.5	-0.34	Buhawi, Nov. 14, 2013	5-Year
88	6.771895	125.335991	1.05	1	-0.05	Buhawi, Nov. 14, 2013	5-Year
89	6.767875	125.336357	1.07	1	-0.07	Buhawi, Nov. 14, 2013	5-Year
90	6.771863	125.341181	1.3	0.7	-0.60	Buhawi, Nov. 14, 2013	5-Year
91	6.766357	125.336799	1.5	2.6	1.10	Buhawi, Nov. 14, 2013	5-Year
92	6.767445	125.336470	2.1	1.2	-0.90	Buhawi, Nov. 14, 2013	5-Year
93	6.765809	125.341022	2.15	6.1	3.95	Buhawi, Nov. 14, 2013	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
94	6.765746	125.337370	2.42	2.8	0.38	Buhawi, Nov. 14, 2013	5-Year
95	6.766666	125.336648	2.68	1.5	-1.18	Buhawi, Nov. 14, 2013	5-Year
96	6.766128	125.340863	5.02	7.9	2.88	Buhawi, Nov. 14, 2013	5-Year
97	6.765363	125.340033	5.03	5.8	0.77	Buhawi, Nov. 14, 2013	5-Year
98	6.765932	125.337285	5.25	4.6	-0.65	Buhawi, Nov. 14, 2013	5-Year
99	6.765458	125.338201	5.67	4.8	-0.87	Buhawi, Nov. 14, 2013	5-Year
100	6.765084	125.341266	6.3	7	0.70	Buhawi, Nov. 14, 2013	5-Year
101	6.765584	125.341224	7.53	8.5	0.97	Buhawi, Nov. 14, 2013	5-Year
102	6.760673	125.352006	0.03	0	-0.03	No Flood	5-Year
103	6.760137	125.357898	0.03	0	-0.03	No Flood	5-Year
104	6.759840	125.354136	0.06	0.5	0.44	Buhawi, Nov. 14, 2013	5-Year
105	6.761974	125.349945	0.06	0.1	0.04	Buhawi, Nov. 14, 2013	5-Year
106	6.758525	125.359029	0.1	0	-0.10	No Flood	5-Year
107	6.762050	125.353984	0.17	6	5.83	Buhawi, Nov. 14, 2013	5-Year
108	6.763989	125.346604	0.24	0	-0.24	No Flood	5-Year
109	6.761779	125.358536	0.28	0	-0.28	No Flood	5-Year
110	6.761207	125.355131	0.29	0	-0.29	No Flood	5-Year
111	6.757502	125.361866	0.4	0	-0.40	No Flood	5-Year
112	6.758275	125.361815	0.42	0.4	-0.02	Buhawi, Nov. 14, 2013	5-Year
113	6.762507	125.355036	0.46	0	-0.46	No Flood	5-Year
114	6.760926	125.347502	0.51	0	-0.51	No Flood	5-Year
115	6.759301	125.360173	0.52	0	-0.52	No Flood	5-Year
116	6.763178	125.359650	0.53	0.5	-0.03	Buhawi, Nov. 14, 2013	5-Year
117	6.756284	125.365595	0.55	0	-0.55	No Flood	5-Year
118	6.756585	125.358000	0.63	0.5	-0.13	Buhawi, Nov. 14, 2013	5-Year
119	6.756771	125.360206	0.66	0.5	-0.16	Buhawi, Nov. 14, 2013	5-Year
120	6.762803	125.353689	0.69	0	-0.69	No Flood	5-Year
121	6.761129	125.357829	1.07	0	-1.07	No Flood	5-Year
122	6.760429	125.358330	1.07	3.6	2.53	Buhawi, Nov. 14, 2013	5-Year
123	6.762340	125.350218	1.17	2.4	1.23	Buhawi, Nov. 14, 2013	5-Year
124	6.765644	125.345056	1.19	0	-1.19	No Flood	5-Year
125	6.765351	125.345216	1.2	0	-1.20	No Flood	5-Year
126	6.763236	125.348692	1.23	2.3	1.07	Bagyong Yolanda, Nov. 7, 2013	5-Year
127	6.761908	125.351475	1.26	4	2.74	Buhawi, Nov. 14, 2013	5-Year
128	6.758441	125.362431	1.38	1	-0.38	Buhawi, Nov. 14, 2013	5-Year
129	6.763407	125.353927	1.4	0.6	-0.80	Buhawi, Nov. 14, 2013	5-Year
130	6.760589	125.359333	1.43	2.6	1.17	Buhawi, Nov. 14, 2013	5-Year
131	6.756788	125.362958	1.57	2.7	1.13	Buhawi, Nov. 14, 2013	5-Year
132	6.757702	125.362290	1.69	3.5	1.81	Buhawi, Nov. 14, 2013	5-Year
133	6.763771	125.354036	1.76	0.5	-1.26	Drainage Overflow	5-Year
134	6.761453	125.354314	2.03	0	-2.03	No Flood	5-Year
135	6.762449	125.353173	2.03	2	-0.03	Heavy rain	5-Year
136	6.760620	125.357415	2.07		-2.07	No Flood	5-Year
137	6.761955	125.352657	2.1	2	-0.10	Buhawi, Nov. 14, 2013	5-Year
138	6.761151	125.353920	2.11	3.9	1.79	Buhawi, Nov. 14, 2013	5-Year
139	6.756785	125.363164	2.15	2.7	0.55	Buhawi, Nov. 14, 2013	5-Year
140	6.760486	125.358568	2.15	3.5	1.35	Buhawi, Nov. 14, 2013	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
141	6.756049	125.363486	2.16	2.5	0.34	Buhawi, Nov. 14, 2013	5-Year
142	6.762822	125.352063	2.2	2	-0.20	Buhawi, Nov. 14, 2013	5-Year
143	6.763322	125.347893	2.23	1.4	-0.83	Bagyong Yolanda, Nov. 7, 2013	5-Year
144	6.757504	125.362421	2.33	2.4	0.07	Buhawi, Nov. 14, 2013	5-Year
145	6.760300	125.357835	2.36	2	-0.36	Buhawi, Nov. 14, 2013	5-Year
146	6.760969	125.354460	2.37	5.7	3.33	Yolanda, Nov. 7, 2013	5-Year
147	6.759119	125.362028	2.55	2.9	0.35	Buhawi, Nov. 14, 2013	5-Year
148	6.760725	125.355399	2.66	5	2.34	Buhawi, Nov. 14, 2013	5-Year
149	6.763226	125.349141	2.9	3	0.10	Bagyong Yolanda, Nov. 7, 2013	5-Year
150	6.764762	125.343488	4.55	5	0.45	Buhawi, Nov. 14, 2013	5-Year
151	6.763352	125.348478	5.04	6	0.96	Bagyong Yolanda, Nov. 7, 2013	5-Year
152	6.764389	125.344017	5.08	4	-1.08	Buhawi, Nov. 14, 2013	5-Year
153	6.760474	125.358071	5.08	3.8	-1.28	Buhawi, Nov. 14, 2013	5-Year
154	6.755573	125.364143	5.09	6.5	1.41	Buhawi, Nov. 14, 2013	5-Year
155	6.761584	125.360995	5.16	6	0.84	Buhawi, Nov. 14, 2013	5-Year
156	6.760391	125.357334	5.19	5	-0.19	Nakayama	5-Year
157	6.761714	125.353956	5.2	0	-5.20	No Flood	5-Year
158	6.756871	125.364317	5.22	6.3	1.08	Buhawi, Nov. 14, 2013	5-Year
159	6.763833	125.348126	5.24	5	-0.24	Buhawi, Nov. 14, 2013	5-Year
160	6.763243	125.345310	5.27	3.6	-1.67	Bagyong Yolanda, Nov. 7, 2013	5-Year
161	6.763935	125.344559	5.31	3.5	-1.81	Bagyong Yolanda, Nov. 7, 2013	5-Year
162	6.760031	125.361591	5.31	5	-0.31	Buhawi, Nov. 14, 2013	5-Year
163	6.760995	125.354850	5.33	6.5	1.17	Buhawi, Nov. 14, 2013	5-Year
164	6.761849	125.353173	5.35	5.2	-0.15	Buhawi, Nov. 14, 2013	5-Year
165	6.763229	125.346547	5.35	5	-0.35	Buhawi, Nov. 14, 2013	5-Year
166	6.761410	125.353629	5.41	5.7	0.29	Buhawi, Nov. 14, 2013	5-Year
167	6.757607	125.363788	5.42	5.8	0.38	Buhawi, Nov. 14, 2013	5-Year
168	6.756478	125.363635	5.5	5.6	0.10	Buhawi, Nov. 14, 2013	5-Year
169	6.763665	125.345015	5.53	2.8	-2.73	Bagyong Yolanda, Nov. 7, 2013	5-Year
170	6.760537	125.355583	5.57	6.9	1.33	Buhawi, Nov. 14, 2013	5-Year
171	6.758553	125.362562	5.72	6.1	0.38	Buhawi, Nov. 14, 2013	5-Year
172	6.762448	125.352417	5.86	5.2	-0.66	Buhawi, Nov. 14, 2013	5-Year
173	6.760691	125.354982	5.93	6.5	0.57	Buhawi, Nov. 14, 2013	5-Year
174	6.763645	125.349165	5.98	7.2	1.22	Buhawi, Nov. 14, 2013	5-Year
175	6.759784	125.347944	0.03	0.1	0.07	Rain	5-Year
176	6.761841	125.343916	0.03	0	-0.03	No Flood	5-Year
177	6.749542	125.353177	0.06	0	-0.06	No Flood	5-Year
178	6.752186	125.362124	0.07	0	-0.07	No Flood	5-Year
179	6.755519	125.360454	0.08	0	-0.08	No Flood	5-Year
180	6.755783	125.361242	0.22	0.2	-0.02	Rain	5-Year
181	6.757078	125.351072	0.23	0.8	0.57	Buhawi, Nov. 14, 2013	5-Year
182	6.755343	125.353906	0.25	0	-0.25	No Flood	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
183	6.754277	125.363561	2.33	0	-2.33	No Flood	5-Year
184	6.753890	125.355606	0.51	0.35	-0.16	Buhawi, Nov. 14, 2013	5-Year
185	6.755444	125.363488	0.26	1.7	1.44	Buhawi, Nov. 14, 2013	5-Year
186	6.755252	125.363662	2.33	2.8	0.47	Buhawi, Nov. 14, 2013	5-Year
187	6.754654	125.363810	2.96	2.2	-0.76	Buhawi, Nov. 14, 2013	5-Year
188	6.753841	125.364652	3.03	4.9	1.87	Buhawi, Nov. 14, 2013	5-Year
189	6.754024	125.364070	4.06	4.5	0.44	Buhawi, Nov. 14, 2013	5-Year
190	6.754303	125.363982	5.74	6.9	1.16	Buhawi, Nov. 14, 2013	5-Year
191	6.722034	125.372386	1.04	0.1	-0.94	Sealevel rise	5-Year
192	6.718825	125.373174	1.08	0	-1.08	No Flood	5-Year
193	6.720548	125.359031	1.13	2	0.87	Bagyong Titang	5-Year
194	6.724939	125.371988	1.15	0.3	-0.85	Heavy rain	5-Year
195	6.727982	125.372687	1.17	0.75	-0.42	Buhawi, Nov. 14, 2013	5-Year
196	6.719770	125.364715	1.31	1	-0.31	Rain in upstream	5-Year
197	6.721177	125.364740	1.34	0	-1.34	No Flood	5-Year
198	6.719149	125.364242	1.42	1.1	-0.32	Buhawi, Nov. 14, 2013	5-Year
199	6.719595	125.362486	1.52	0.5	-1.02	Buhawi, Nov. 14, 2013	5-Year
200	6.739273	125.385636	0.63	0.6	-0.03	Buhawi, Nov. 14, 2013	5-Year
				RMSE	1.072873		

Annex 12. Educational Institutions Affected in Digos Floodplain

Table A-12.1. Educational Institutions in Digos City, Davao del Sur Affected by Flooding in Digos Floodplain

Davao del Sur				
Digos City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ACCEL PRE-SCHOOL, INC.	Aplaya	Low	Medium	Medium
APLAYA ELEMENTARY CHOOL	Aplaya	Low	Medium	Medium
APLAYA ELEMENTARY SCHOOL	Aplaya	Low	Medium	Medium
APLAYA ELENTARY ELEMENTARY SCHOOL	Aplaya	Low	Low	Medium
APLAYA ELENTARY SCHOOL	Aplaya	Low	Low	Medium
ASIAN ACCELERATED ACADEMY	Aplaya			
BETHESDA BAPTIST CHRISTIAN ACADEMY	Aplaya			
CRUMB BATAAN DAY CARE	Aplaya		Low	Low
DAY CARE CENTER	Aplaya		Low	Low
DAY CARE CENTER CHRISTIAN VILLAGE	Aplaya			
DIGOS CHRISTIAN LEARNING CENTER	Aplaya			Low
DIGOS TECH	Aplaya			
DON MARIANO ELEMENTARY SCHOOL	Aplaya	Low	Low	Medium
MINDANAO MONTESSORI SCHOOL	Aplaya			
MINTECH	Aplaya	Low	Low	Low
PRE SCHOOL	Aplaya			
RAMON MAGSAYSAY CENTRAL ELEMENTARY SCHOOL	Aplaya	Low	Low	Low
SAVER'S COLLEGE	Aplaya	Low	Medium	Medium
SOUTHERN MINDANAO COMPUTER COLLEGE	Aplaya	Low	Low	Low
UNITED CHURCH OF CHRIST IN THE PHILIPPINES KINDERGARTEN MISSION SCHOOL	Aplaya	Medium	Medium	Medium
DAY CARE CENTER	Cogon	Medium	Medium	Medium
LORNA V. LEARNING CENTER	Cogon		Low	Low
PEDRO GARCIA ELEMENTARY SCHOOL	Cogon		Low	Low
PEDRO GARCIA ELEMENTARY SCHOOL CANTEEN	Cogon		Low	Low
ABBY KOREAN LANGUAGE TUTORIAL CENTER	Dawis			

AMSAI (PRESCHOOL AND ELEMENTARY)	Dawis			
DAWIS DAY CARE CENTER	Dawis		Low	Low
DAWIS ELEMENTARY SCHOOL	Dawis	Low	Low	Low
DAY CARE CENTER	Dawis			
ISAAC ABALAYAN ELEMENTARY SCHOOL	Dawis	Low	Low	Low
SOUTH WILL LEARING CENTER	Dawis			
DAY CARE CENTER	Goma			
RUPARAN DAY CARE CENTER	Ruparan	Low	Low	Low
RUPARAN ELEMENTARY SCHOOL	Ruparan			
RUPARAN ELEMENTARY SCHOOL	San Agustin			Low
RUPARAN NATIONAL HIGH SCHOOL	San Agustin		Low	Low
DAY CARE CENTER	San Jose	Low	Low	Low
DIGOS CENTRAL ADVENTIST ACADEMY	San Jose			
DIGOS CITY-BRILLIANT CHILD ACADEMY, INC.	San Jose			Low
GREGORIO M. REUSORA CENTRAL ELEMENTARY SCHOOL	Sinawilan			
GREGORIO M. REUSORA DAY CARE	Sinawilan			
KIAGOT DAY CARE CENTER	Sinawilan	Low	Medium	Medium
CAVITE BIBLE BAPTIST ACADEMY	Tres de Mayo			
DAY CARE CENTER	Tres de Mayo			
JOLENCIO ALBERCA ELEMENTARY SCHOOL	Tres de Mayo		Low	Low
COR JESU COLLEGE	Zone 1			
DAY CARE CENTER	Zone 1			
KAMACHILLE DAYCARE	Zone 1			
POLYTECHIC COLLEGE DAVAO DEL SUR	Zone 1	Medium	Medium	Medium
CLASSHOMES DAY CARE	Zone 2			Low
DAY CARE CENTER	Zone 2	Medium	Medium	Medium
DAY CARE CENTER BARANGAY ZONE 1	Zone 2			
DIGOS CENTRAL ELEMENTARY SCHOOL	Zone 2	Low	Low	Medium
POLYTECHIC COLLEGE DAVAO DEL SUR	Zone 2	Low	Low	Medium

BIBLE BAPTIST KINDERGARTEN	Zone 3			
COR JESU COLLEGE	Zone 3			
DAY CARE CENTER/STAGE	Zone 3	Low	Low	Low
DIGOS CENTRAL ELEMENTARY SCHOOL	Zone 3	Low	Low	Medium
DIGOS CITY NATIONAL HIGH SCHOOL	Zone 3	Low	Low	Low
GYM (COR JESO COLLEGE)	Zone 3	Low	Low	Medium
HOLY CROSS ACADEMY INC	Zone 3			
HOLY CROSS ACADEMY INC.	Zone 3	Medium	Medium	Medium
HOLY FAMILY DAY CARE CENTER	Zone 3			
JESUS IS LORD SCHOOL	Zone 3			Low
LITTLE AMBASSADOR CHILD DEVELOPMENT CENTER OF DIGOS INC.	Zone 3			
LITTLE HANDS LEARNING CENTER	Zone 3			Low
MINTECH	Zone 3		Low	Low
PARKING AREA (COR JESO COLLEGE)	Zone 3	Low	Low	Low
UNIVERSITY OF MINDANAO DIGOS COLLEGE	Zone 3		Low	Low

Annex 13. Medical Institutions Affected in Digos Floodplain

Table A-13.1. Health Institutions in Digos City, Davao del Sur Affected by Flooding in Digos Floodplain

Davao del Sur				
Digos City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ARSENIA DRUG STORE/GOOD SHEPPERD ULTRASOUND CLINIC	Aplaya			
A'S PHARMACY/LABCORP DIAGNOSTIC CENTER	Aplaya			
BARANGAY HEALTH CENTER	Aplaya		Low	Medium
BARANGAY HEALTH CENTER B	Aplaya			
CURATO DENTAL CLINIC	Aplaya	Low	Low	Low
DAVAO DEL SUR PROVINCIAL HOSPITAL	Aplaya		Low	Low
MONGCOS MEDICAL CLINIC	Aplaya			
PAANAKAN LEAH BIRTHING HOME	Aplaya	Low	Low	Low
PAOLINO HOSPITAL	Aplaya	Low	Low	Low
SUNGA HOSPITAL	Aplaya			
VETERENARY CLINIC	Aplaya			
VILLEGAS CLINIC	Aplaya	Low	Low	Low
WONDERLAND PHARMACY	Aplaya		Low	Low
HEALTH CENTER	Cogon			Low
GM TORREGOSO BIRTHING HOME CENTER	Dawis			
MEDIC PHARMA	Dawis			
VIGAR HOSPITAL	Dawis	Low	Medium	Medium
DIGITAL SYSTEM INSTITUTE (HOSPITAL)	San Jose		Low	Low
HEALTH CENTER	Sinawilan	Low	Low	Low
BARANGAY HEALTH STATION (HEALTH CENTER)	Tres de Mayo			
DIGOS HOSPITAL	Zone 1			
HEALTH CENTER	Zone 1			
CARITAS HEALTH SHIELD	Zone 2			Low
DIGOS DOCTORS HOSPITAL EXTENSION	Zone 2		Low	Low

DIGOS HOSPITAL	Zone 2	Low	Low	Low
DIGOS HOSPITAL (CANTEEN)	Zone 2	Medium	Medium	Medium
DIGOS HOSPITAL (PARKING AREA)	Zone 2			
LLANOS MEDICAL CLINIC & HOSPITAL	Zone 2			
MEDICAL CENTER OF DIGOS CITY	Zone 2			
ACEBEDO OPTICAL	Zone 3			
ARENDAIN-KINTANAR MEDICAL CLINIC	Zone 3	Low	Medium	Medium
BONE AND SKIN SPECIALIST	Zone 3			
DOMINICAN HOSPITAL	Zone 3	Low	Medium	Medium
DURAY VERNON CLINIC	Zone 3		Low	Low
GONZALES MARANAN MEDICAL CENTER INCORPORATED	Zone 3			
J.A MASONGSONG CHILD CLINIC	Zone 3			
KAHAYAG OPTICAL CLINIC	Zone 3			
KIDNEY CENTER	Zone 3			
M.L TORRES CHILLDREN'S CLINIC	Zone 3			
MEDICAL CENTER OF DIGOS CITY	Zone 3			
ZONE 2 HEALTH CENTER	Zone 3	Medium	Medium	Medium