REGION 11

Tagum River:

DREAM Ground Surveys Report

TRAINING CENTER FOR APPLIED GEODESY AND PHOTOGRAMMETRY

2015

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List of Abbreviations

ADCP	Acoustic Doppler Current Profiler
AWLS	Automated Water Level Sensor
BM	Benchmark
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DG	Depth Gauge
DOST	Department of Science and Technology
DPC	Data Processing Component
DREAM	Disaster Risk Exposure and Assessment for Mitigation
DVC	Data Validation Component
EGM 2008	Earth Gravitation Model 2008
FMC	Flood Modeling Component
GCP	Ground Control Point
GE	Geodetic Engineer
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
LGUs	Local Government Units
LiDAR	Light Detection and Ranging
MSL	Mean Sea Level
NAMRIA	National Mapping and Resource Information Authority
PCG	Philippine Coast Guard
PDRRMC	Provincial Disaster Risk Reduction Management Council
PPA	Philippine Ports Authority
PPK	Post Processed Kinematic
RG	Rain Gauge
TBC	Trimble Business Center
TS	Total Station
TCAGP	Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984

Introduction

Introduction

1.1 DREAM Program Overview

The UP Training Center for Applied Geodesy and Photogrammetry (UP TCAGP) conducts a research program entitled "Nationwide Disaster Risk and Exposure Assessment for Mitigation" supported by the Department of Science and Technology (DOST) Grant-in-Aide Program. The DREAM Program aims to produce detailed, up-to-date, national elevation dataset for 3D flood and hazard mapping to address disaster risk reduction and mitigation in the country.

The DREAM Program consists of four components that operationalize the various stages of implementation. The Data Acquisition Component (DAC) conducts aerial surveys to collect LiDAR data and aerial images in major riverbasins and priority areas. The Data Validation Component (DVC) implements ground surveys to validate acquired LiDAR data, along with bathymetric measurements to gather river discharge data. The Data Processing Component (DPC) processes and compiles all data generated by the DAC and DVC. Finally, the Flood Modeling Component (FMC) utilizes compiled data for flood modeling and simulation.

Overall, the target output is a national elevation dataset suitable for 1:5000 scale mapping, with 50 centimeter horizontal and vertical accuracies, respectively. These accuracies are achieved through the use of state-of-the-art airborne Light Detection and Ranging (LiDAR) Systems collects point cloud data at a rate of 100,000 to 500,000 points per second, and is capable of collecting elevation data at a rate of 300 to 400 square kilometer per day, per sensor.

1.2 Objectives and Target Outputs

The program aims to achieve the following objectives:

a) To acquire a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management,

b) To operationalize the development of flood hazard models that would produce up dated and detailed flood hazard maps for the major river systems in the country,

c) To develop the capacity to process, produce and analyze various proven and potential thematic map layers from the 3D data useful for government agencies,

d) To transfer product development technologies to government agencies with geo spatial information requirements, and,

e) To generate the following outputs
   1) flood hazard map
   2) digital surface model
   3) digital terrain model and
   4) orthophotograph

1.3 General Methodological Framework

The methodology employed to accomplish the project's expected outputs are subdivided into four (4) major components, as shown in Figure 1. Each component is described in detail in the following sections.

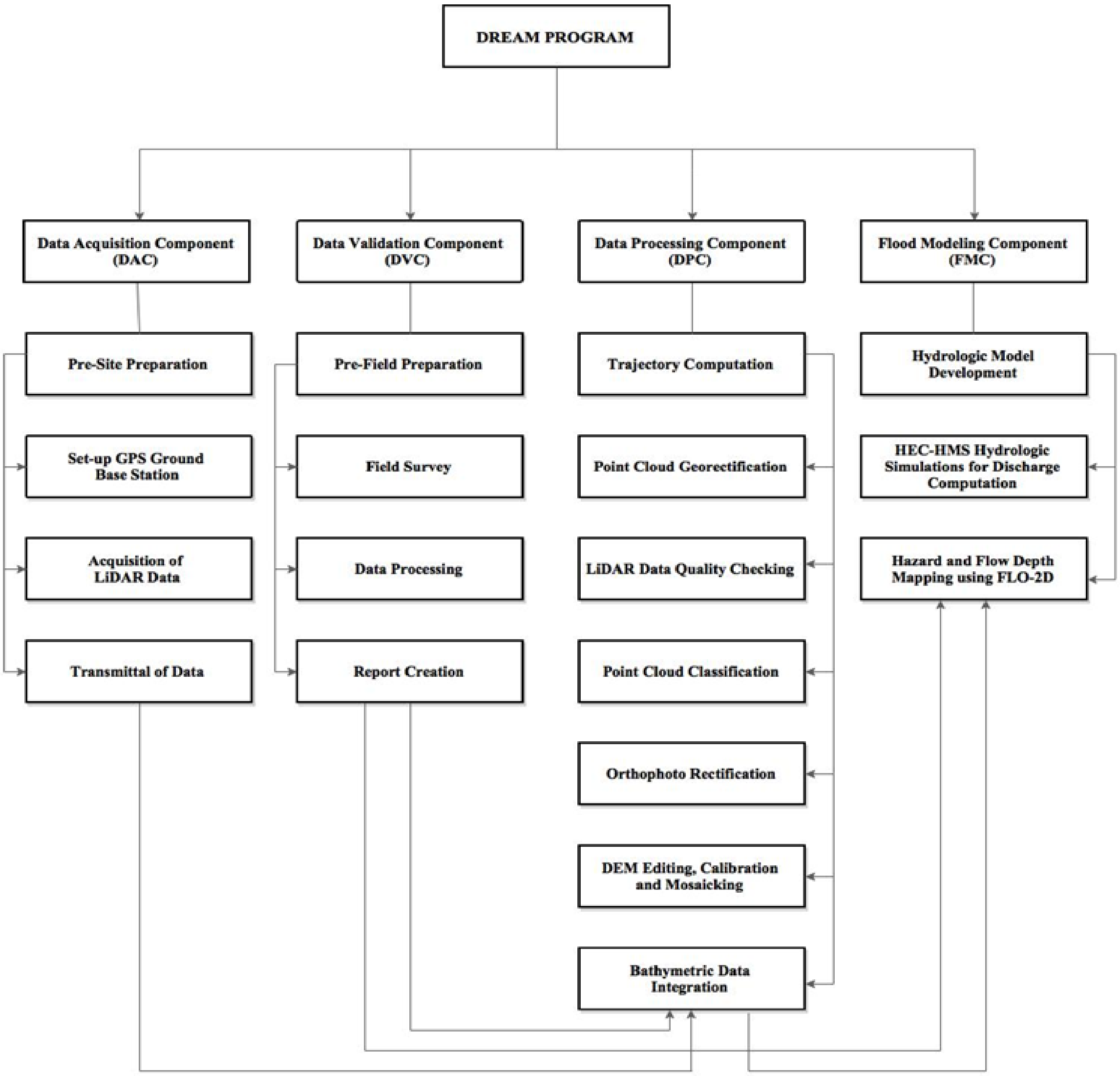

Figure 1. The General Methodological Framework of the Program

The Tagum River Basin

The Tagum River Basin

The Tagum River Basin is located in Mindanao. It is considered as the tenth largest river basin in the Philippines It covers an estimated basin area of 2,734 square kilometres. The location of Tagum River Basin is shown in Figure 2.

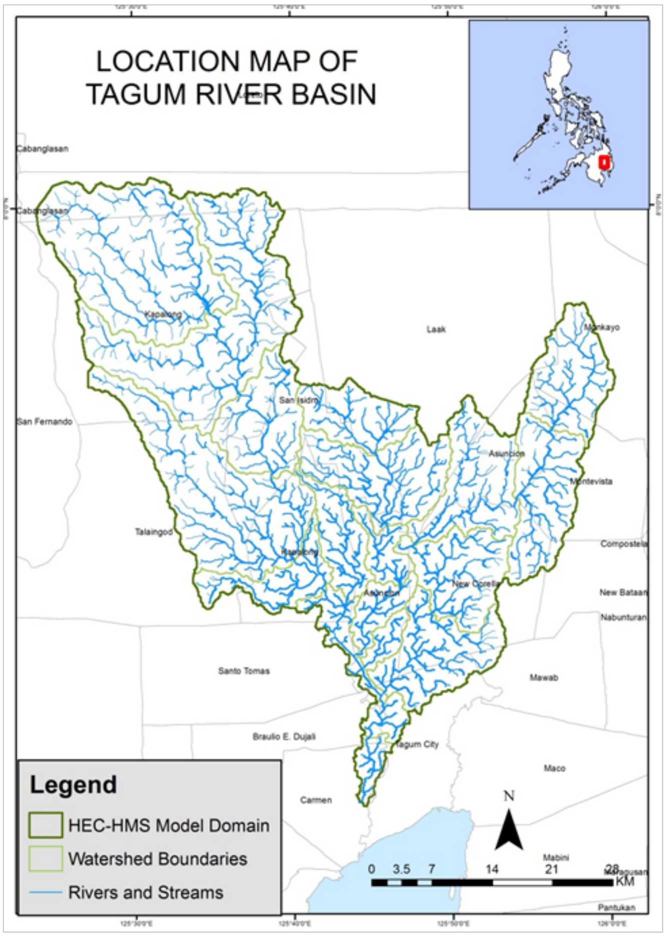

Figure 2. The Tagum River Basin Location Map

It encompasses the provinces of Agusan del Sur, Compostela Valley and Davao del Norte. It drains the southern portion of the island and traverses through Tagum City and the towns of Laak, Monkayo, Montevista, and Nabunturan in Compostela Valley; Kapalong, San Isidro, Talaingod, Asuncion, New Corella , Santo Tomas, Braulio E. Dujali, Carmen, and Mawab in Davao del Norte; and Veruela in Agusan del Sur.

The land and soil characteristics are important parameters used in assigning the roughness coefficient for different areas within the river basin. The roughness coefficient, also called Manning's coefficient, represents the variable flow of water in different land covers (i.e. rougher, restricted flow within vegetated areas, smoother flow within channels and fluvial environments).

The Tagum River Basin

The shape files of the soil and land cover were taken from the Bureau of Soils, which is under the Department of Environment and Natural Resources (DENR) Management, and National Mapping and Resource Information Authority (NAMRIA). The soil and land cover of the Tagum River Basin are shown in Figure 3 and Figure 4, respectively.

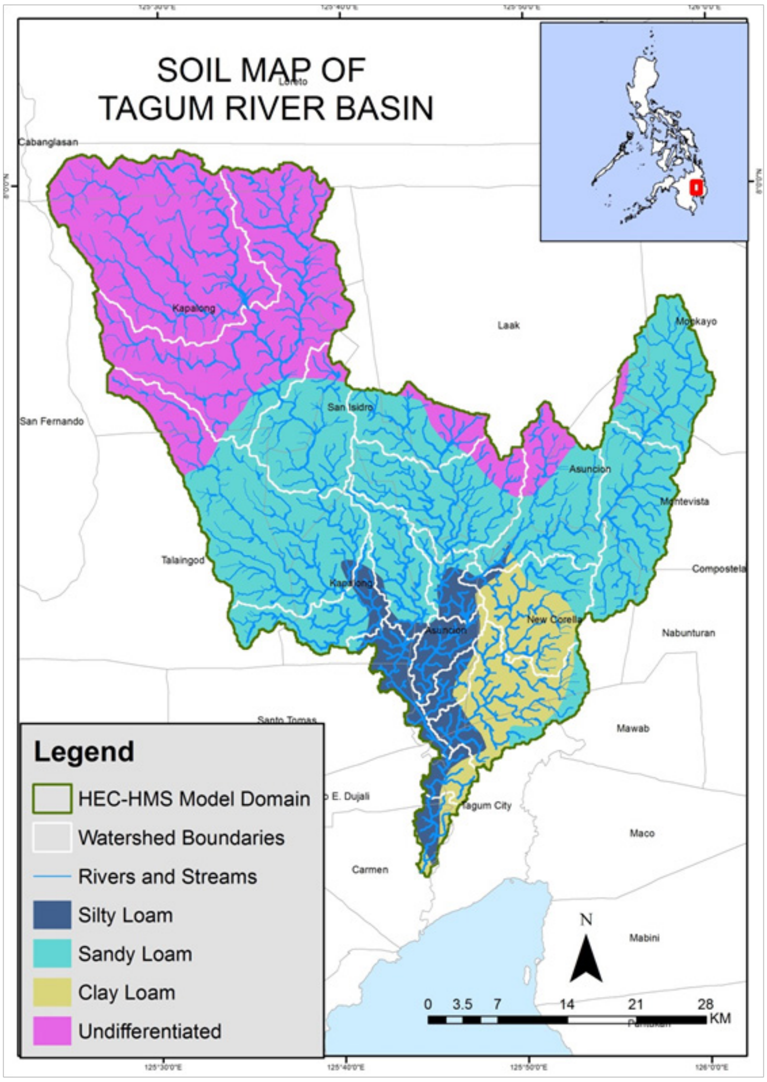

Figure 3. Tagum River Basin Soil Map

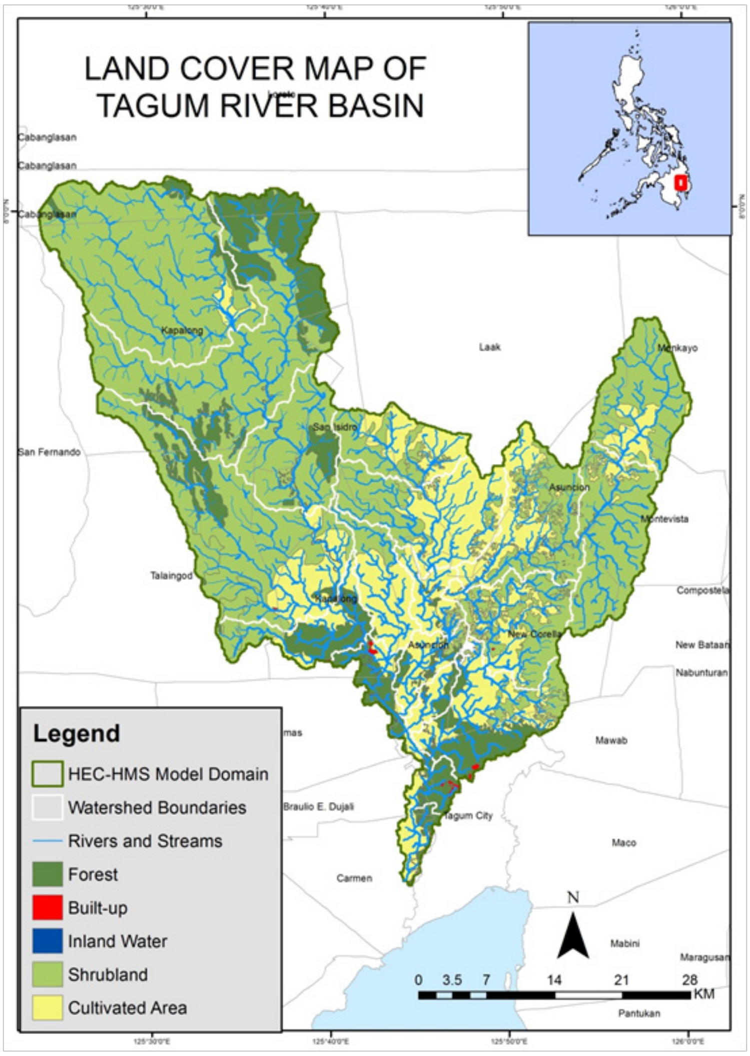

Figure 4. Tagum River Basin Land Cover Map

DVC Methodology

DVC Methodology

A set of activities were designed and implemented byDVC with four (4) main activities as shown in Figure 5.

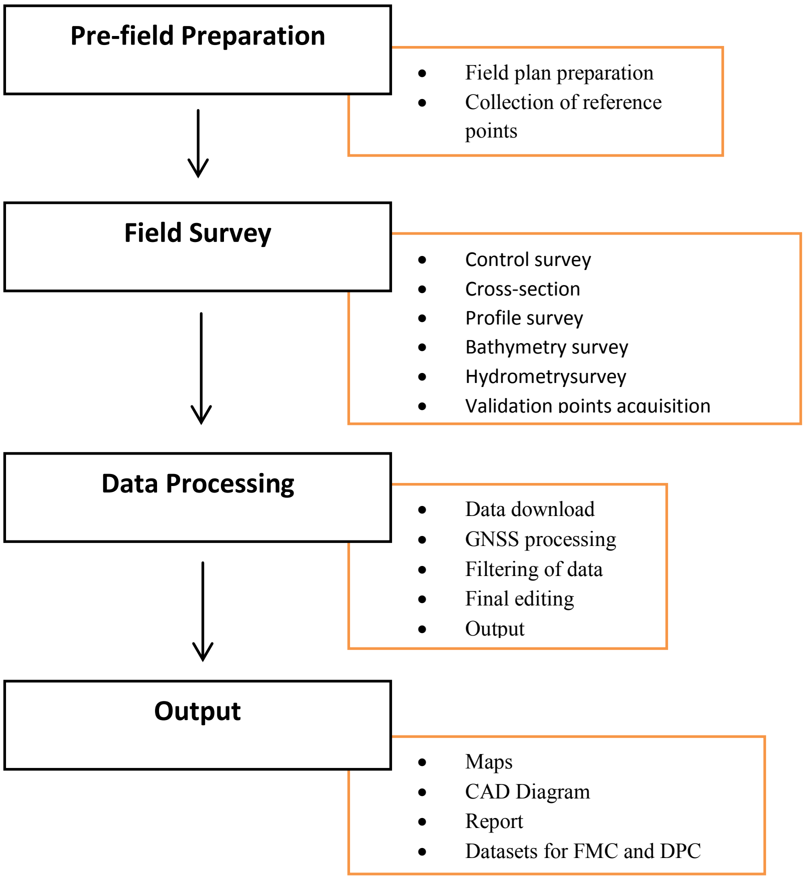

Figure 5. DVC Main Activities

DVC Methodology

3.1 Pre-field Preparation

3.1.1 Preparation of Field Plan

The planning for research fieldwork considers all the necessary technical and logistical concerns conceptualized in a field plan.

This serves as a basis and guide of the survey team in the implementation of the fieldwork activities and included the following activities:

- Delineation of bathymetry lines and determination of the river basin extent using Google Earth® images and available topographic maps;
- Listing and preparation of the survey equipment and other materials needed;
- Designation of tasks to DVC members for the field survey;
- Approximation of field duration and cost based on the delineated survey extent; and
- Assessment of the initial field plan by the program management for approval and implementation.

3.1.2 Collection of Reference Points

Technical data and other relevant information are collected from the National Mapping and Resource Information Authority (NAMRIA) such as locations and descriptions of established horizontal and vertical control points with a minimum of 2nd order accuracy. These ground control points and benchmarks are selected and occupied as primary reference points for the establishment of a GNSS network for the survey.

3.2 Field Surveys

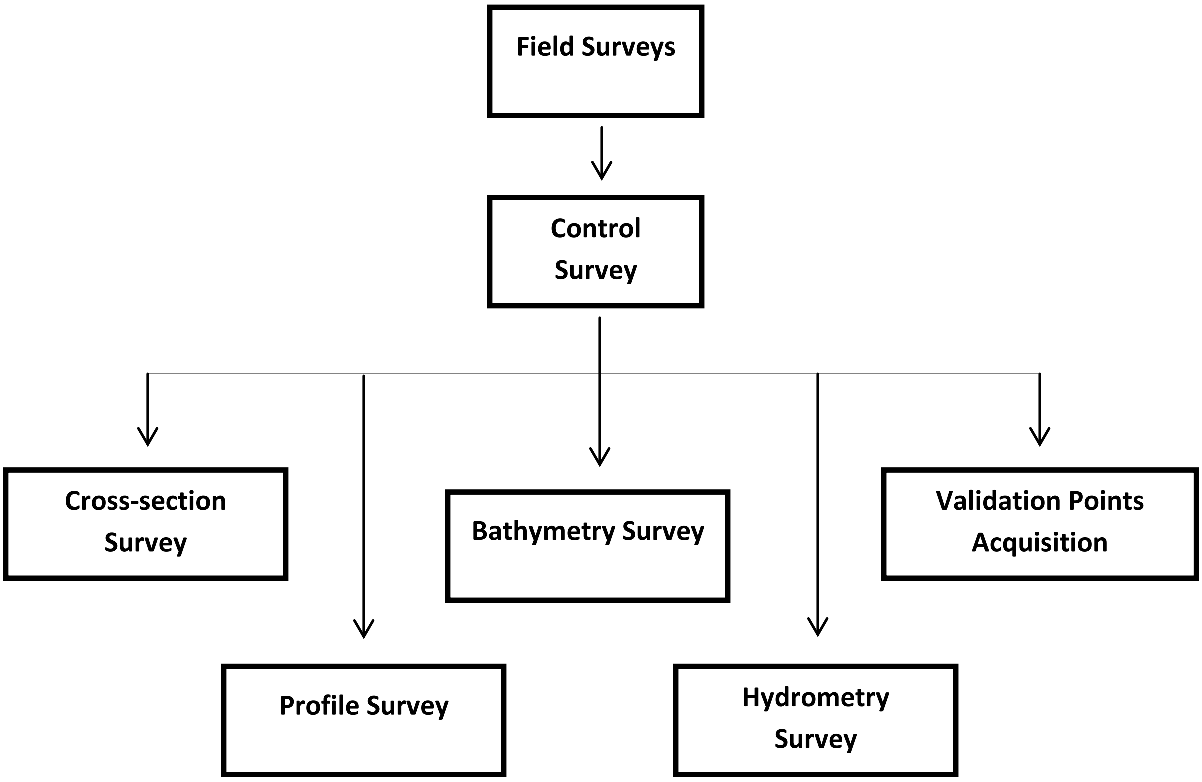

Figure 6. DVC Field Activities

3.2.1 Control Survey

A GNSS network is established through occupation of reference points with dual frequency GNSS receivers for four (4) hours. Reference points from NAMRIA only bear vertical coordinates (z or elevation value) and horizontal coordinates (x and y values) for benchmarks and ground control points, respectively.

Control survey aims to provide both the horizontal and vertical position for every control point established through network adjustment. Horizontal position is acquired through static survey while establishment of vertical position can be done either using a Total Station (TS) or digital level or through static survey.

For the vertical position control survey using a TS or Level, a double run is carried out connecting the nearest existing NAMRIA benchmarks (BMs) to the control point. A double run consists of a forward run (from BM to GCP) and backward run (from GCP to BM). The accuracy shall be assessed and accepted if it is within the third order differential leveling standard.

A benchmark may be used to refer elevation data to Mean Sea Level (MSL) within 20-km radius. Additional benchmarks are located for survey areas exceeding this 20-km radius

Establishment of a GNSS network through control survey is pre-requisite for the conduct of other ground survey activities.Reference and control points occupied for the control survey may serve as base stations throughout the survey area.

3.2.2 Cross-Section Survey

The objective of this activity is to derive a sectional view of the main river and the flood plain (right and left banks). Cross-sections are surveyed perpendicular to the riverbanks with an average length of 100 meters for each bank. The cross-section line shall follow the path of the nearby road or goat trails with a 10-meter interval for each point measurement. Additional points are obtained to describe apparent change in elevation along the cross-section line. Each cross-section is identified sequentially from upstream to downstream direction.

Cross-section surveys are done using dual frequency GNSS receivers and differential kinematic GNSS survey technique. The accuracy of the horizontal position and elevation of each individual cross-section surveys is within ±20 cm for horizontal and ±10 cm for vertical position residuals.

Areas where kinematic GNSS survey is not applicable due to the presence of obstructions such as tall structures and canopy of trees, conventional surveying techniques such as total stations and level are used to collect cross-sectional data.

3.2.3 Profile Surveys

Profile surveys are conducted to obtain the upper and lower banks of the river. This data is overlaid with LIDAR data to delineate the longitudinal extent of the river.

A profile survey consists of the Left Upper Bank (LUB) and Left Lower Bank (LLB), Right Upper Bank (RUB) and Right Lower Bank (RLB). An interval between successive profile points is approximately 10 meters. Additional points are gathered to describe apparent change in elevation along the profile line

Profile surveys are conducted using dual frequency GNSS receivers and kinematic survey technique with a prescribed vertical accuracies of ±20 cm for horizontal and ±10 cm for vertical position, respectively. Conventional surveying techniques such as total stations and level are used to collect profile data for areas where kinematic GNSS survey is not applicable due to obstructions such as tall structures and canopy of trees.

3.2.4 Bathymetric Survey

Bathymetric survey is performed using a survey-grade single beam echo sounder capable of logging time-stamped depth value in centimetre and dual frequency GNSS using kinematic survey technique, with prescribed vertical accuracies of ±20 cm for horizontal and ±10 cm for vertical position for rivers navigable by boat. Data acquisition is logged at one second intervals both for GPS positions and elevation and echo sounder depth reading

For portions of the river that is not navigable by boat due to shallow water, less than a meter, riverbed may be acquired using manual bathymetric survey. Manual bathymetric survey means manually acquiring riverbed points without the use of an echo sounder. It can be done using a GPS receiver, Total Station or Level.

3.2.5 Hydrometric Survey

Hydrometric survey consists of deployment of flow gathering sensors in order to produce a Stage-Discharge (HQ) computation for specific locations in the river such as in its upstream, tributaries, and downstream. This is done to determine the behaviour of the river given specific precipitation levels.

The elements of discharge computation are the ff.:

- River flow data – river flow data can be acquired using an Acoustic Doppler Current Profiler (ADCP) orby mechanical or digital flow meters. River flow data sensors measure velocity of the river for a specific time period and interval.
- Cross-section data – cross section data is acquired using dual frequency GPS receivers to obtain the cross-section area of the river. Cross-section area of a river changes in time as influenced by water level change.
- Water level change – water level change is measured using either a depth gauge or an Automated Water Level Sensor (AWLS) installed by DOST. Depth gauges relates pressure to water level change while AWLS uses laser pulsed at specific time intervals for measurement.
- Water surface elevation – water surface elevation in MSL is measured near the banks of the river with dual frequency GPS receivers. This will refer the measured water level change to a corresponding elevation value in MSL in order to derive Stage, or water level height a particular time.

Precipitation is the biggest factor influencing stage and river velocity. These two(2) sets of data must be synchronized by time in order to compute for its cross-section area, and subsequently, for discharge.

The element of time is crucial in determining the delay between the onset of precipitation and the time of significant water level change along key points of the river for early flood warning system of communities. The correlation of stage-discharge computation is used for calibrating flood-simulation programs utilized by the Flood Modeling Component (FMC).

The summary of elements for discharge computation is illustrated in Figure 7.

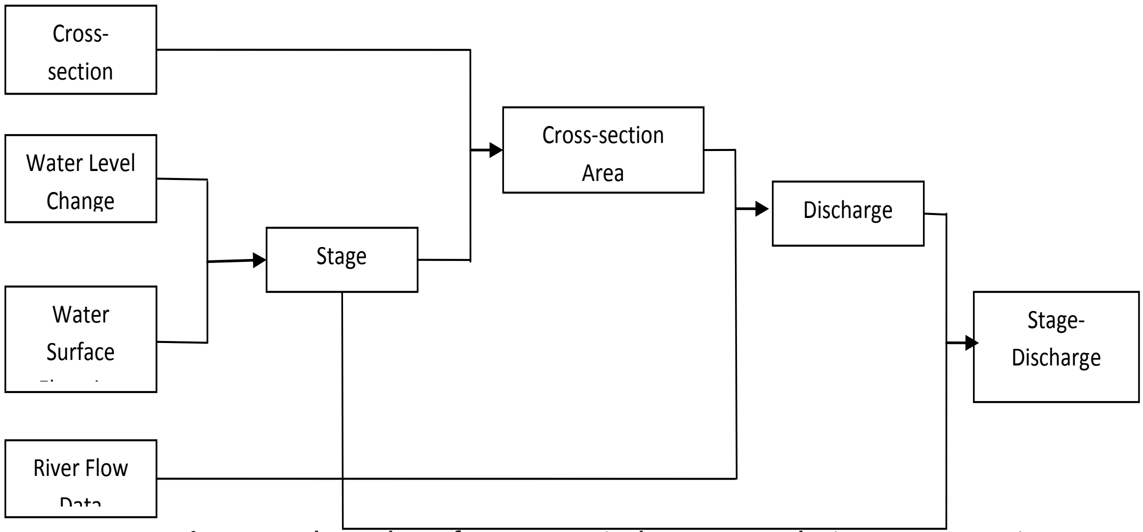

Figure 7. Flow Chart for Stage-Discharge Correlation Computation

3.2.6 Validation Points Acquisition Survey

Ground validation survey is conducted for quality checking purpose of the Aerial LiDAR data acquired by the Data Acquisition Component (DAC). A roving GNSS receiver is mounted on a range pole attached to a vehicle to gather points thru continuous topo method in a PPK Survey Technique. Points are measured along major roads and highway across the flight strips provided by DAC.

GNSS surveys setup used to accomplish DVC's field survey activities are illustrated in Figure 8.

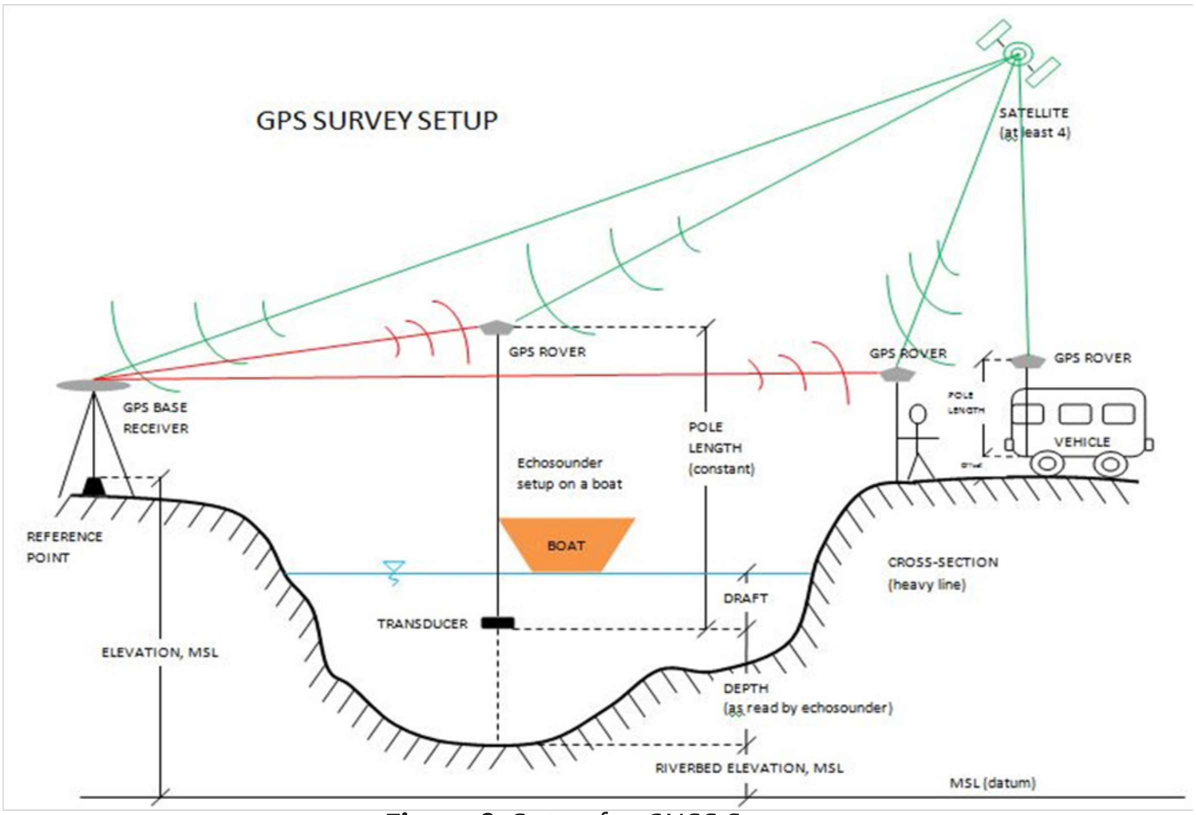

Figure 8. Setup for GNSS Surveys

3.3 Data Processing

Data processing procedures used by DVC are summarized in Figure 9

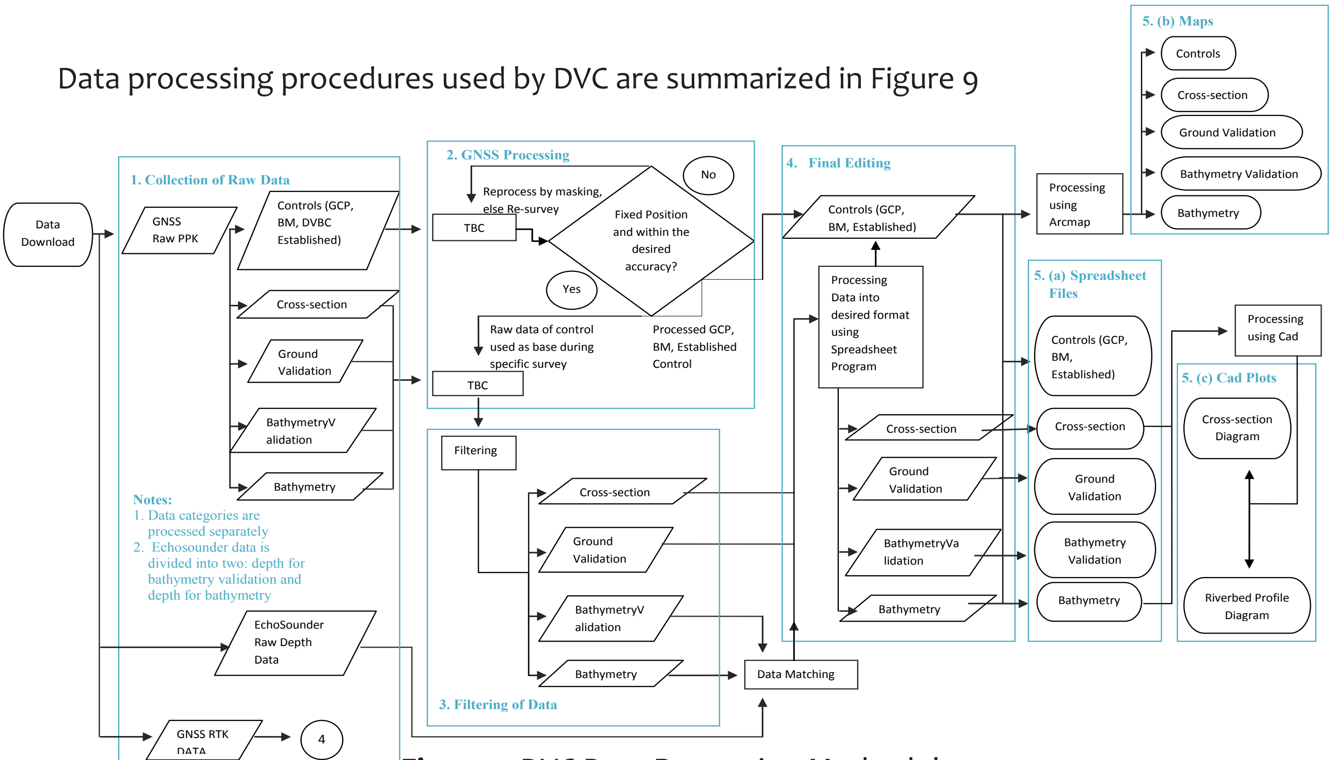

Figure 9.DVC Data Processing Methodology

3.3.1 Collection of Raw Data

GPS Raw data in (*.t02) format are downloaded from Trimble®GPS receivers used in static, cross-section, LiDAR ground validation, and bathymetric surveys. Depth values in (*.som) files from bathymetric surveys are also downloaded from OHMEX™ echo sounder.

3.3.2 Data Processing

Processing for GNSS Data

The horizontal and vertical coordinates of the reference point used as base station are held fixed, based on its NAMRIA certification, for the establishment of a GNSS network for the survey area. Coordinates of this fixed point is used to give horizontal and vertical coordinates for the other reference points occupied and control points established.

Data from GNSS control surveys are processed in Trimble® Business Center (TBC) software and settings were set to the required accuracy of +/-10cm for vertical and +/-20cm for horizontal controls. The TBC coordinate system parameters were set to Universal Transverse Mercator (UTM) Zone 51 North, World Geodetic System of 1984 (WGS1984), and the geoid model EGM2008 for horizontal and vertical datum, respectively.

An offset is derived by comparing the MSL elevation of the benchmark stated in the NAMRIA certification and its elevation value that resulted from the processed and adjusted control survey. This offset is used to refer all elevation from other surveys into MSL (BM_Ortho).

The formulas used for offset and BM_Ortho computation are shown in Equations 1-2:

Computation for offset:

Equation 1: $OFFSET = BM - EGM$

Computation for BM_ortho:

Equation 2: $BM_{Ortho} = EGM_{Ortho} \pm OFFSET$

where:

- ***OFFSET*** = difference/offset between Geoid model, EGM 2008 and MSL datum. Can be a positive or negative value
- ***BM*** = MSL elevation of vertical control point certified by NAMRIA
- ***EGM*** = EGM2008 elevation of the same NAMRIA vertical control point derived from TBC software processing
- ***EGM*** $_{\_Ortho}$ = elevation of points referred to geoid model, EGM 2008
- ***BM*** $_{\_Ortho}$ = elevation of points referred to MSL

GNSS processing is also done for the other surveys with the coordinates from the occupied points for the control survey held fixed, depending on which base station is used for the survey.

Processed and adjusted data are exported to comma delimited (*.csv) file format with the ff. columns: Point Name, Latitude, Longitude, Ellipsoidal Height, Northing, Easting, and Elevation (EGM_Ortho). This file format can be accessed through Microsoft Excel/Spreadsheet program.

Depth Data Processing

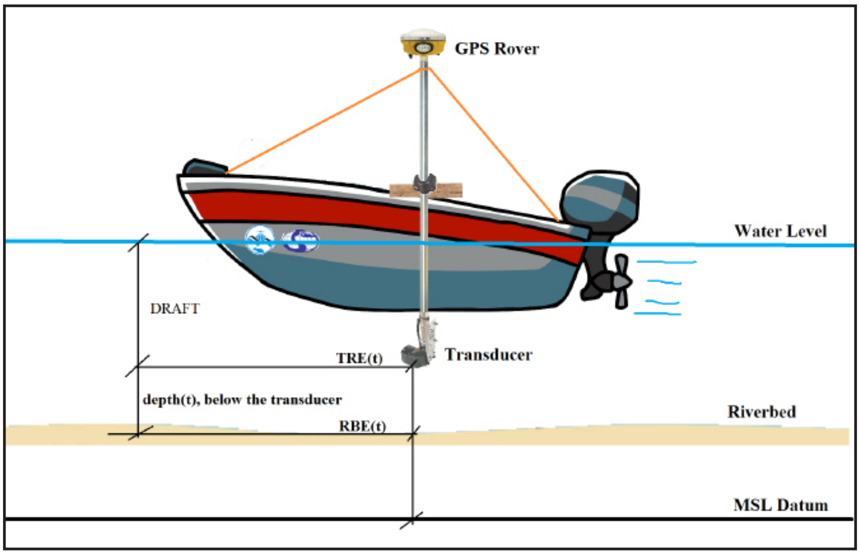

Figure 10. Illustration of Echo Sounder and GPS rover set-up for Bathymetric survey

There are two types of echo sounders used for bathymetric surveys – Hi-Target™ single beam echo sounder which is capable of recording depth data of one decimal place and the OHMEX™ single beam echo sounder capable of recording two-decimal places of depth data.

Raw depth data from Hi-Target™ single beam echo sounder is exported in (*.txt) file format with the ff. columns: Point No., Time, Depths H, Depths L, Draft, and Sound Velocity. This (*.txt) file is copied to a spreadsheet, retaining only the columns for Time and Depths H.

DVC Methodology

Raw depth data from OHMEX™ single beam echo sounder are exported in (*.som) file format. It is imported into SonarVista then exported into *.csv format with the ff. columns: Type, Date/Time, Sec, X/E, Y/N, Z/H, Tide, Depth and QA. SonarVista is used as file conversion tool only. The (*.csv) file opened using spreadsheet, making use of only the columns for Date/Time and Depth.

Data Matching for Bathymetric Data

Data matching is done by pairing an individual attribute of a bathymetric point to a depth data acquired using either OHMEX or HI-Target echo sounder. Matching is possible by ensuring that both bathymetric points and depth values acquisition has time stamp capability. These two sets of data are matched using VLOOKUP tool of a spreadsheet program, such that each point will have an accompanying (x,y,z) and depth data.

Below is the formula used for computing the elevation of the riverbed:

Equation 3:

$$RBE(t) = TRE(t) - Depth(t)$$

where:

RBE(t) = elevation of the riverbed during time t,

TRE(t) = transducer elevation (reckoned from EGM 2008)

Depth(t) = depth recorded by the echo sounder at time t, with the assumption that depth is measured from the bottom of the transducer down to the riverbed

The resulting RBE(t) data are referred to MSL (BM_ortho) by applying the offset for the established network.

Final processed data are imported to Google Earth™ and Geographic Information Systems (GIS) software for viewing and checking horizontal position.

Hydrometry Data Processing

The processes done for Hydrometry data for HQ computation are described in the ff. steps:

1. **River Flow Data**

a.) ADCP

Data from the ADCP is logged internally and can be downloaded using either SonUtils™ or View Argonaut™ software. River velocity is recorded for a specified time duration and interval can be exported in a (*.csv) format.

b.) Flow Meter

Acquisition of river velocity using flow meters is done manually. Measurements for a specified time duration and interval is recorded in a field notebook and saved in a spreadsheet program.

2. **Cross Section and Water Surface Elevation Data**

Cross Section data and water surface elevation data is acquired using GNSS receivers described in section 3.3.4 for GNSS data processing with a resulting file in (*.xls) format.

3. **Water Level Change-Stage**

a.) Depth Gauge

Data from depth gauge can be downloaded using HobowarePro™. Water level in meters are logged for a specific time interval and it can be exported in a (*.csv) format.

b.) AWLS

Data from installed AWLS can be accessed via the internet (http://repo.pscigrid.gov.ph/predict/). Water levels are logged in ten-minute time intervals and can be copied into a spreadsheet program.

4. **Discharge Computation**

River flow data and water level change is synchronized by time. Parameters were preset in its respective programs so the deployment of each instrument will begin and end in the same time. All data in (*.csv) and (*.csv) format are combined in a single worksheet wherein the computation for the coefficient of determination or R2 are done.

The illustration in Figure 7 shows how each set of data from each instrument can be synchronized.

3.3.3 Filtering of Data

A processed point which resulted to float or did not meet the desired accuracy is filtered out. Resurveys are conducted immediately if data gaps are present for the ground surveys.

3.3.4 Final Editing

Final editing is performed to be able to come up with the desired data format: Point Value, Latitude, Longitude, Ellipsoidal Height, Northing, Easting, EGM_Ortho and BM_Ortho.

Processes discussed are valid for static, cross section, ground validation, and manual bathymetric surveys not employing echo sounders. For bathymetric surveys using a single beam echo sounder, the GPS rover is mounted on top of a 2m pole and a transducer at the bottom (see Figure 10). Figure is valid in both using OHMEX and HI-Target echo sounders. The GPS rover provides horizontal and vertical coordinates whereas the echo sounder transducer measures depth of the river from its bottom down to the riverbed.

3.3.5 Output

Filtered data are furthered processed into desired template using a spreadsheet program. Final data are generated into maps and CAD plots for cross-section, profile, and riverbed profiles. Cross-section, Profile, Validation Points, and Bathymetric data shall be turned-over to DPC while hydrometric data shall be turned-over to FMC.

The Tagum River Basin

The Tagum River Basin

The survey for Tagum River Basin was conducted on April 23 to May 08, 2013with the following activities: control, bathymetric, profile, cross-section and hydrometric surveys.

Tagum River consists of 21 delineated cross section lines with a total length of 18.88 km for both left and right banks starting fromBrgy. Esperanzain the upstream down to Brgy.Bincungan-near the mouth of the river. The total length of profile lines is about 26.68 km for its both left and right banks.

On different sets of fieldwork, cross-section and flow measurement surveys were conducted on bridges with AWLS along the Tagum River Networknamely: Ilog Bridge in Asuncion, FVR Nanaga Bridge 1 in Talaingod and Maniki Bridge in Kapalong.

4.1 Control Survey

Three (3) NAMRIA established control points were considered for the static GNSS observations of the three river systems namely: Davao, Hijo and Tagum-Libuganon Rivers. These include a benchmark, DV-76, which is located in Tagum City; a second-order reference point, COV-14, situated in front of Maco Municipal Hall, Compostela Valley; and a first-order reference point, DVS-1, located at Port Area, Sta. Ana Wharf, Davao City. The location of the three (3) base stations are shown inFigure 11 while the GNSS set-up for these controls are shown in Figure 12, Figure 13, and Figure 14.

The reference point COV-14 served as the GNSS base station for Tagum River bathymetry and ground validation survey for aerial LiDAR which is located in Maco, Compostela Valley. Also, it was used to get the horizontal and vertical coordinates of the established control points on the approach of the bridges along the Tagum River System. The offset used for referring elevation to MSL was derived from the GNSS Network established for the Tagum River bathymetric, profile, cross-section and hydrometric surveys on April to May 2013.

Continuous differential static observations were done simultaneously at these three stations for two hours to provide reference control points for the ground and bathymetric surveys. The horizontal coordinates and elevations of the three (3) control points were computed using Trimble™ Business Center GNSS processing software. The result of control survey for the control points are indicated in Table 1.

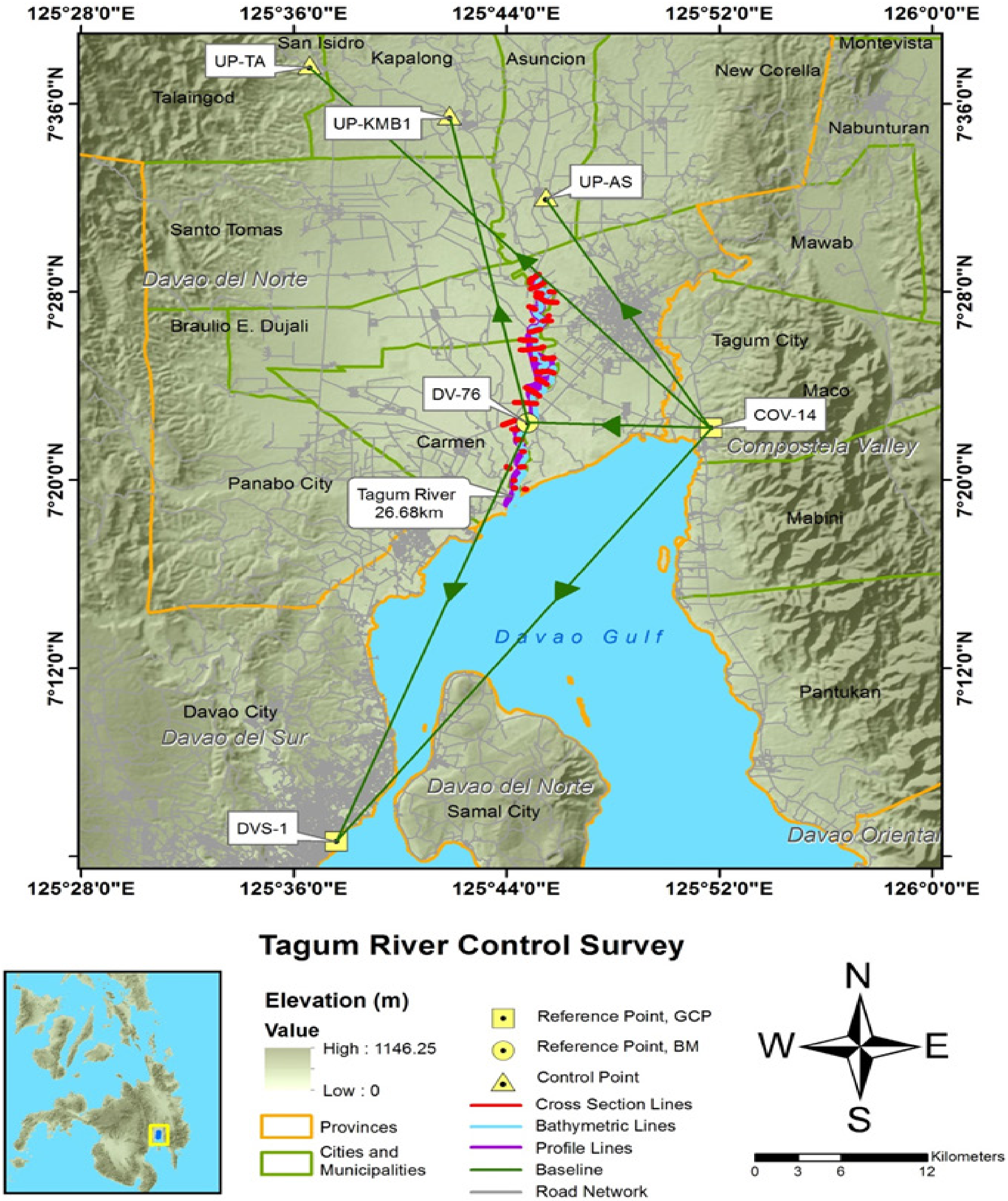

Figure 11. Location of control points

Table 1. Control points occupied during Tagum River Survey (Source: NAMRIA, UP-TCAGP)

Point Name	WGS84 UTM Zone 51N					Elevation in MSL (m)
	Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	
COV-14	7022'13.38586" N	125051'41.73051" E	140.906	815706.706	815937.881	73.257
DV-76	7022'26.51282" N	125044'48.14113" E	75.907	816030.497	803241.596	8.359
DVS-1	7004'38.35565" N	125037'36.76595" E	68.456	783116.508	790192.769	0.974

The GNSS setup for the three (3) control points are illustrated in Figure 12 to Figure 14:

Figure 12. Static GNSS observation at DVS-1 in Port Area, Sta. Ana Wharf, Davao City

Figure 13. Static GNSS observation at DV-76 in Guadalupe Bridge, Tagum City

Figure 14. Static GNSS observation at COV-14 in front of Maco Municipal Hall in Barangay Poblacion, Maco, Compostela Valley

The Tagum River Basin

The established control points along the bridges with installed AWLS served as base stations for the conduct of cross-section surveys. The GNSS set-up in each control point are shown in Figure 15 to Figure 17. The result of this control survey is summarized in Table 2.

Table 2. Established Control Points along the Tagum River System (Source: UP-TCAGP)

Point Name	WGS84 UTM Zone 51N					Elevation in MSL (m)
	Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	
UP-TA	7037'39.19437" N	125036'37.07077" E	117.299	843994.982	788004.462	48.316
UP-AS	7032'03.24804" N	125045'30.14498" E	83.126	833768.810	804419.878	15.103
UP-KMB1	7035'31.30030" N	125041'52.29298" E	91.560	840122.838	797696.855	23.203

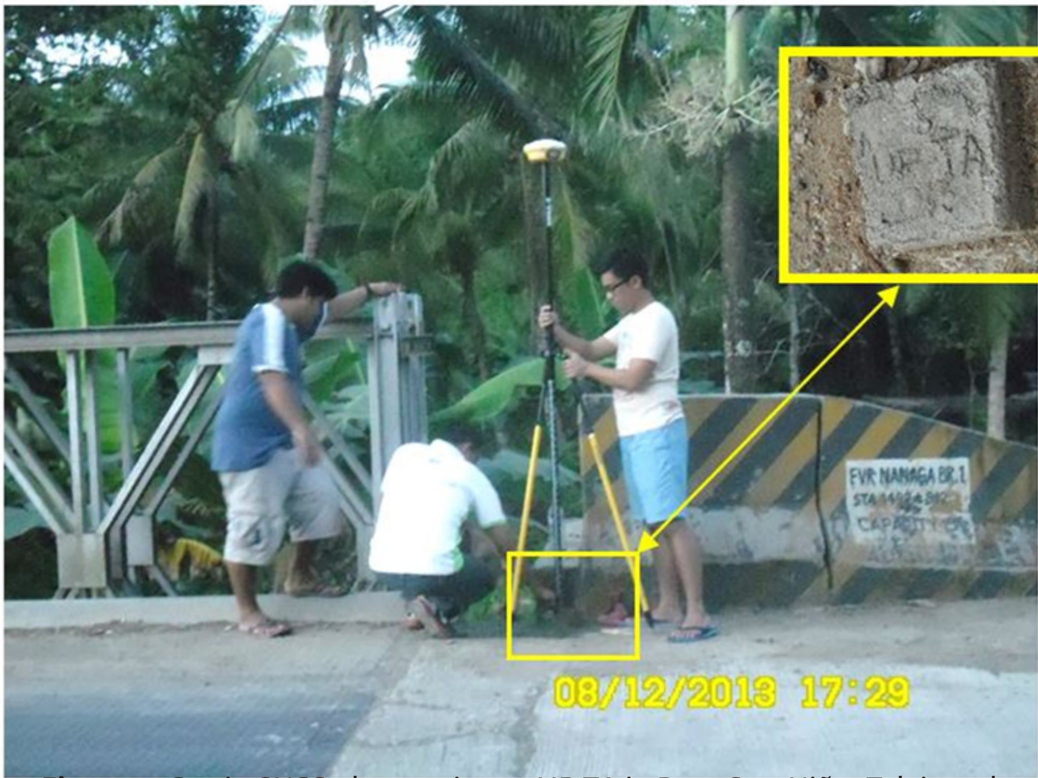

Figure 15. Static GNSS observation at UP-TA in Brgy.Sto. Niño, Talaingod

Figure 16. Static GNSS observation at UP-AS in Brgy.Poblacion, Asuncion

Figure 17. Static GNSS observation at UP-KMB1 in Brgy.Pag-Asa, Kapalong

4.2 Bathymetric Survey

The bathymetry of the river channel was surveyed using an echosounding surveying technique. Differential GNSS surveying technique and an Ohmex™ single beam echosounder were utilized in measuring the depth, eventually obtaining elevation with corresponding horizontal position. Bathymetry setup during the Tagum bathymetry survey is illustrated in Figure 18 and Figure 19.

The entire bathymetry survey took two (2) days to accomplish from May 1 to 2, 2013. The Bathymetry Team executed the survey using a rubber boat borrowed from the Provincial Disaster Risk Reduction Management Council(PDRRMC) as shown in Figure 18 and Figure 19. Centerline and zigzag sweep of the survey were performed in order to fully capture the topography of the river as presented in Figure 20.An approximate centerline length of 22 km were covered starting

Figure 18. Bathymetric survey setup on a rubber boat

Figure 19. Bathymetry team with the member of Tagum City CDDRMC

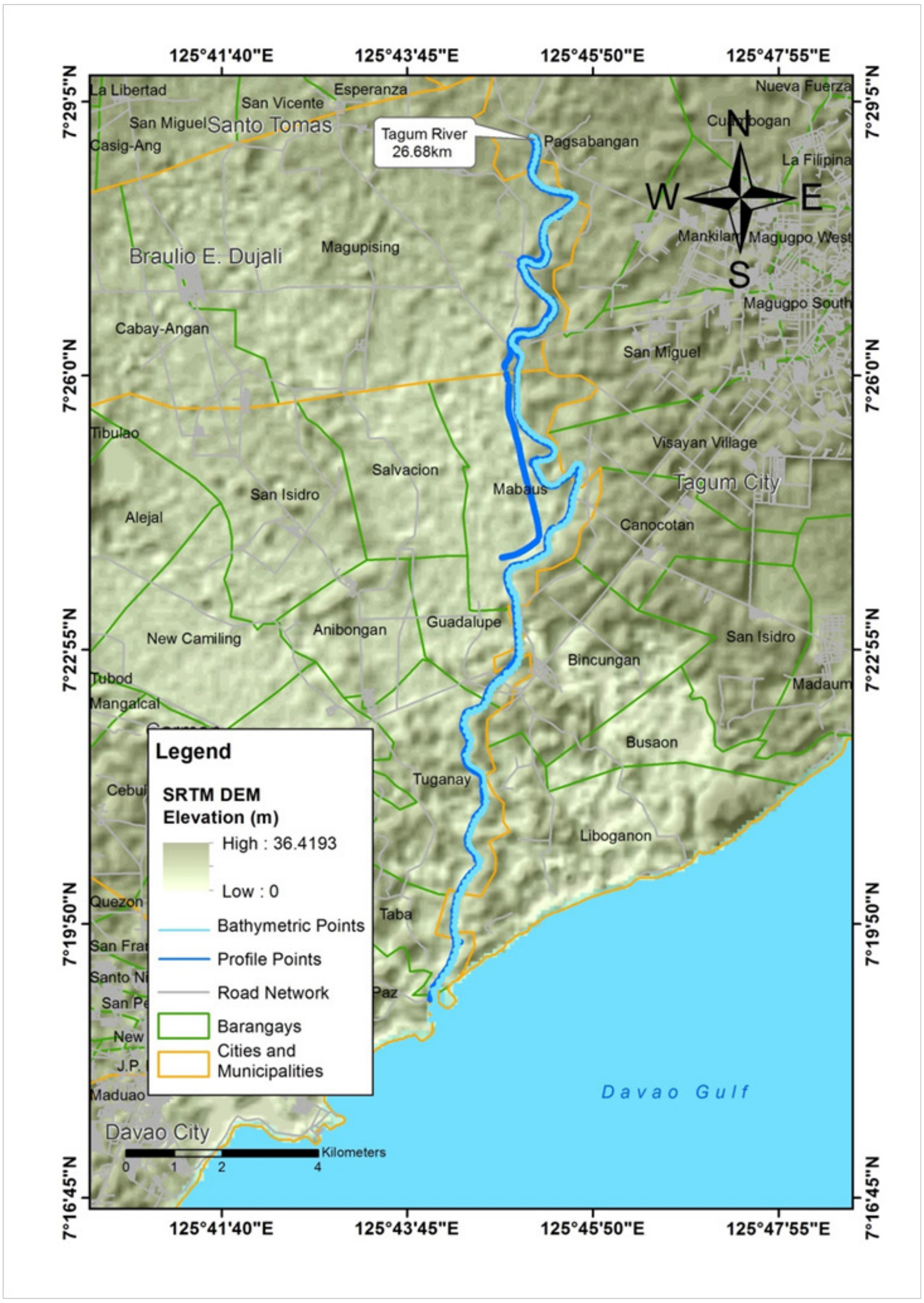

Figure 20. Bathymetric data in Tagum River

4.3 Profile Survey

The banks of the river were surveyed using differential kinematic GNSS surveying techniques. Four (4) teams performed the profile survey where eachteam is composed of one member of DVC and a local hire. Theteams were deployed at both sides of the river in Brgy. Pagsabangan going downstream to Brgy.La Paz, Davao City as shown in Figure 21.There is a change in elevation from upstream to downstream of about 7.05 and 3.25 m in the upper and lower banks, respectively. The profile in each bank is illustrated in Figure 22 to Figure 31.

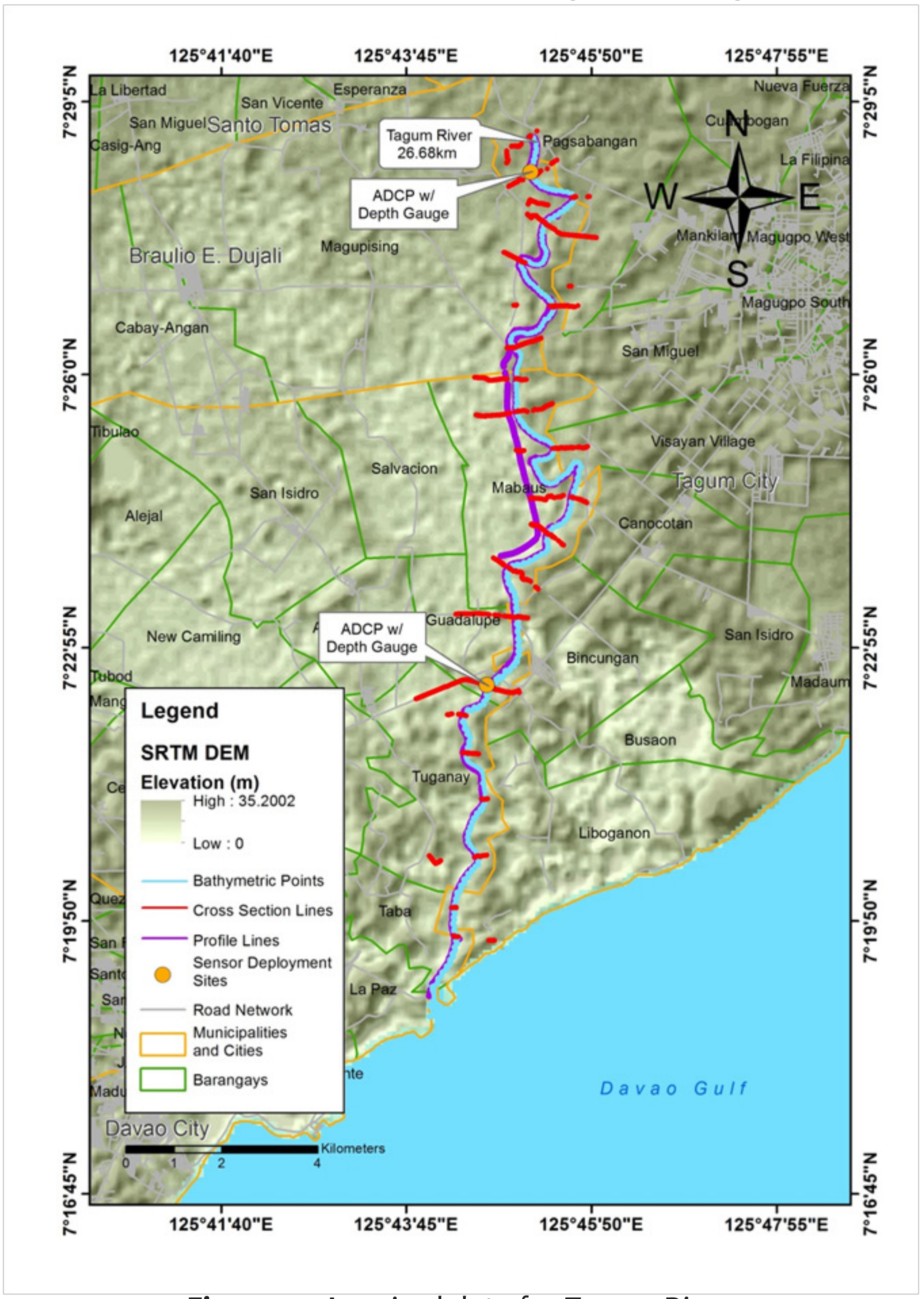

Figure 21. Acquired data for Tagum River

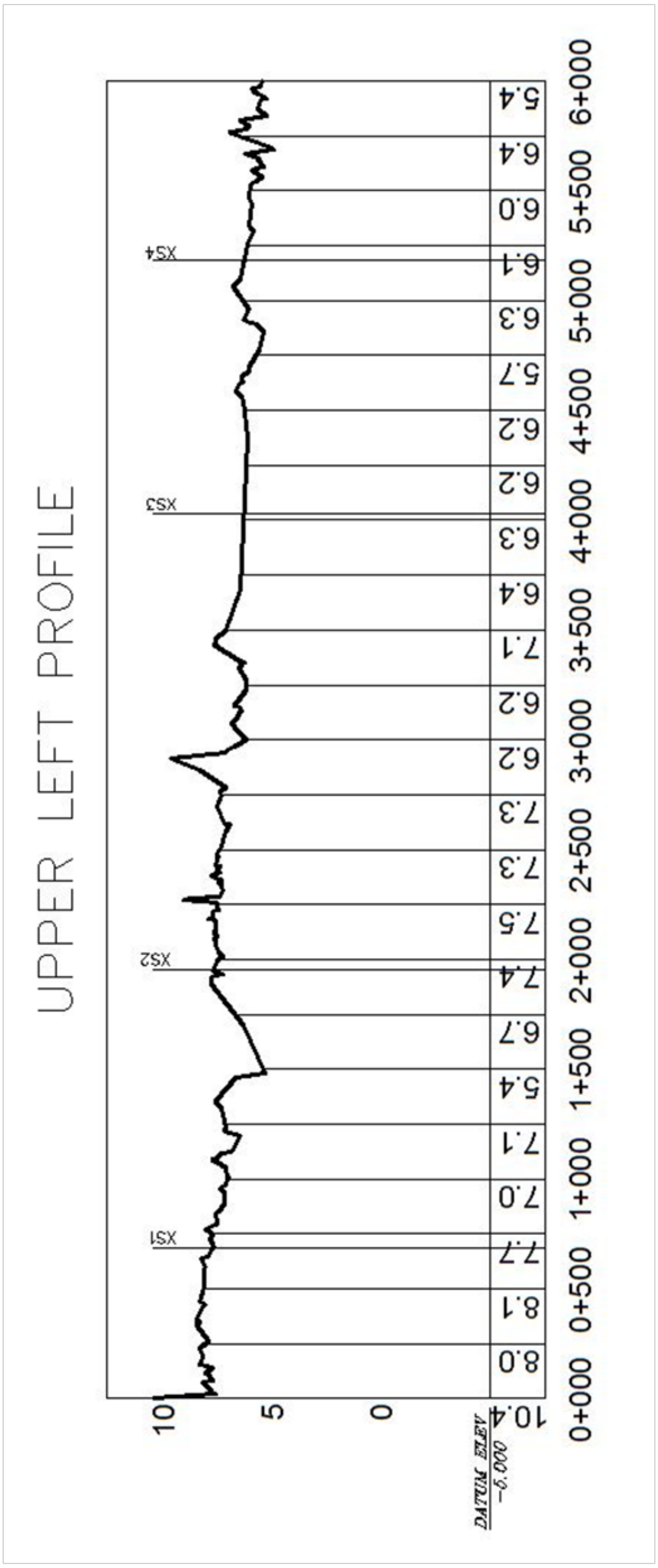

Figure 22. Upper left profile in Tagum River

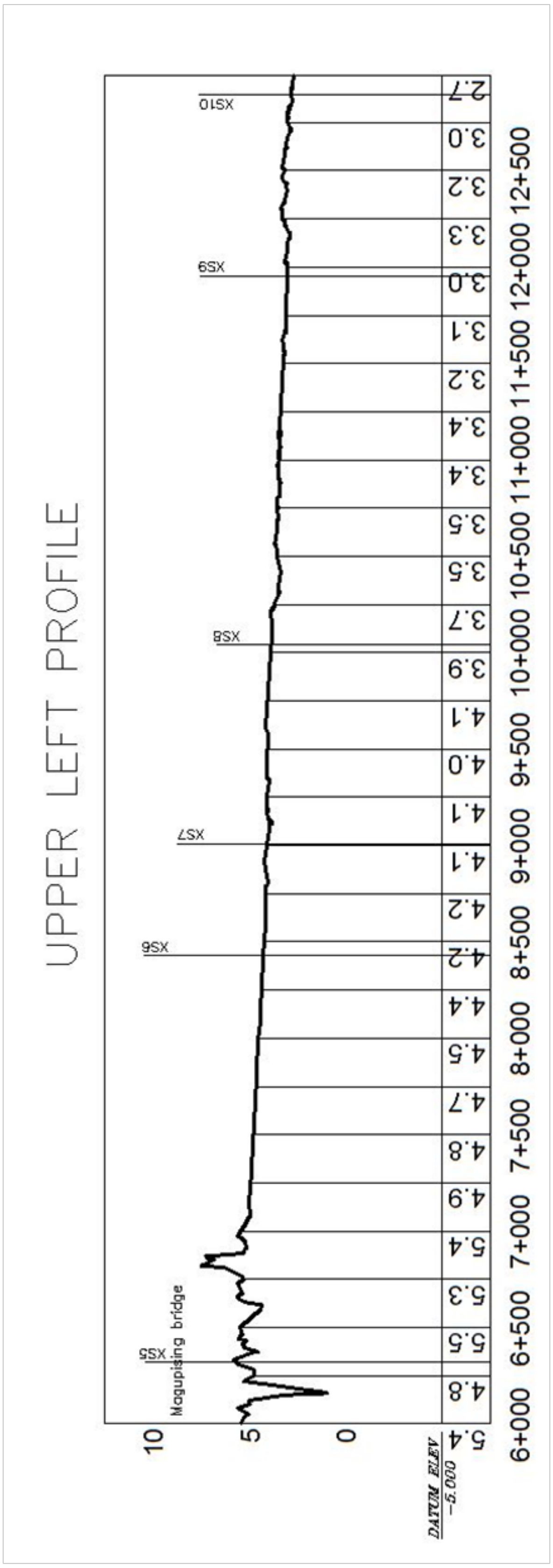

Figure 23. Upper left profile in Tagum River

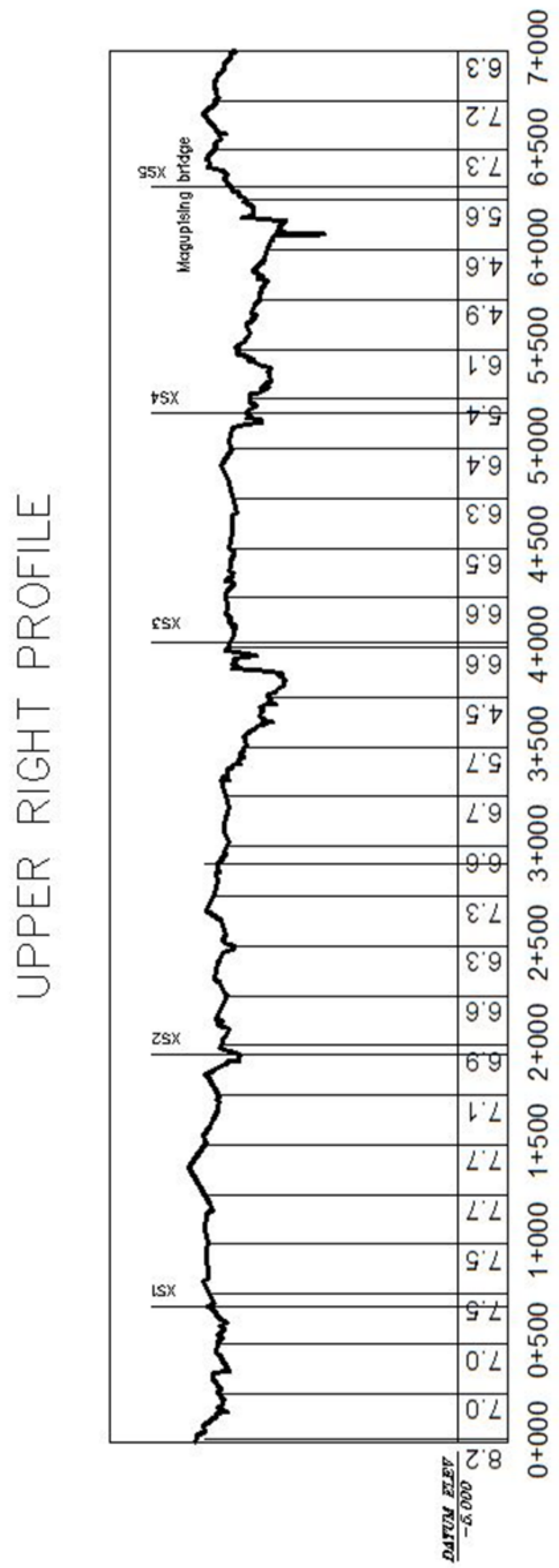

Figure 24. Upper right profile in Tagum River

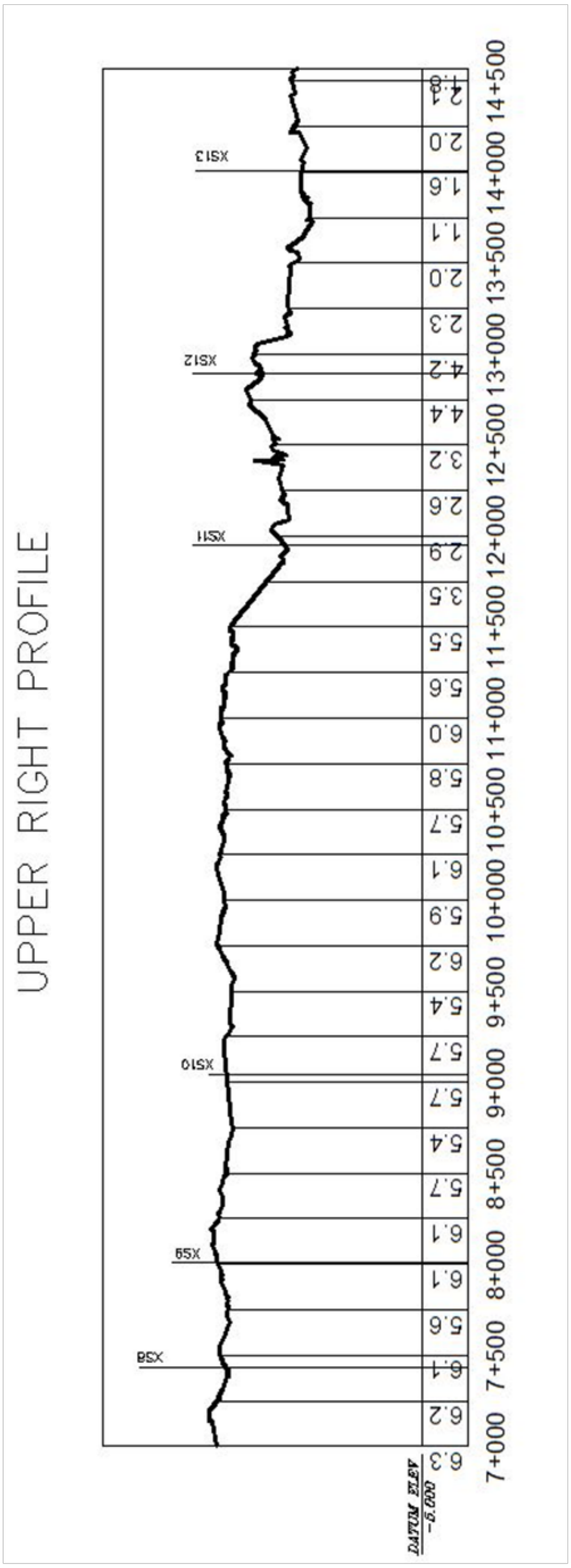

Figure 25. Upper right profile in Tagum River

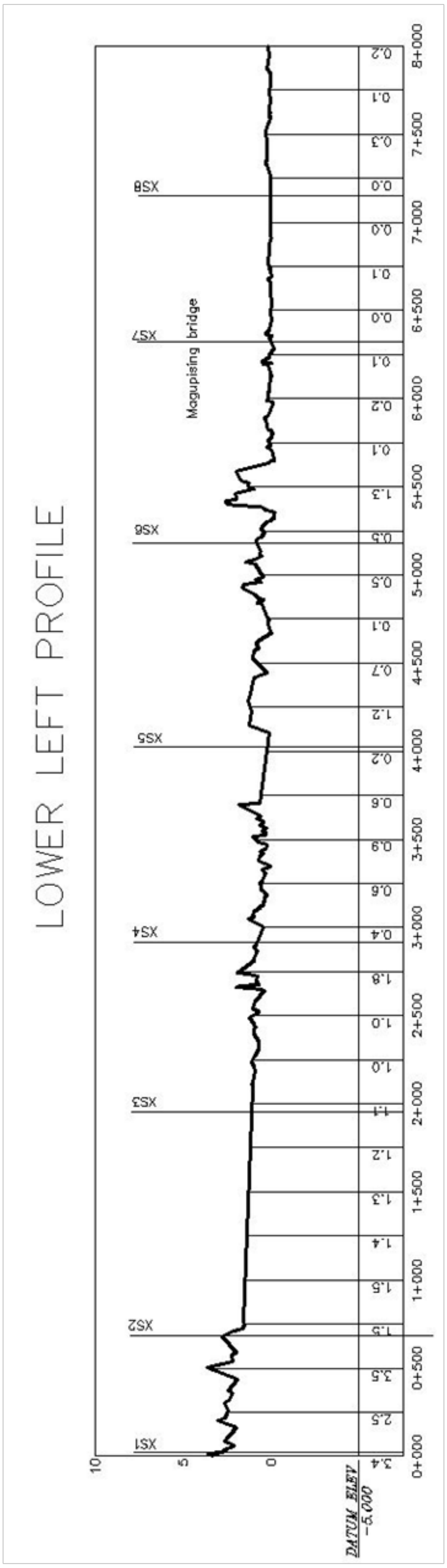

Figure 26. Lower left profile in Tagum River

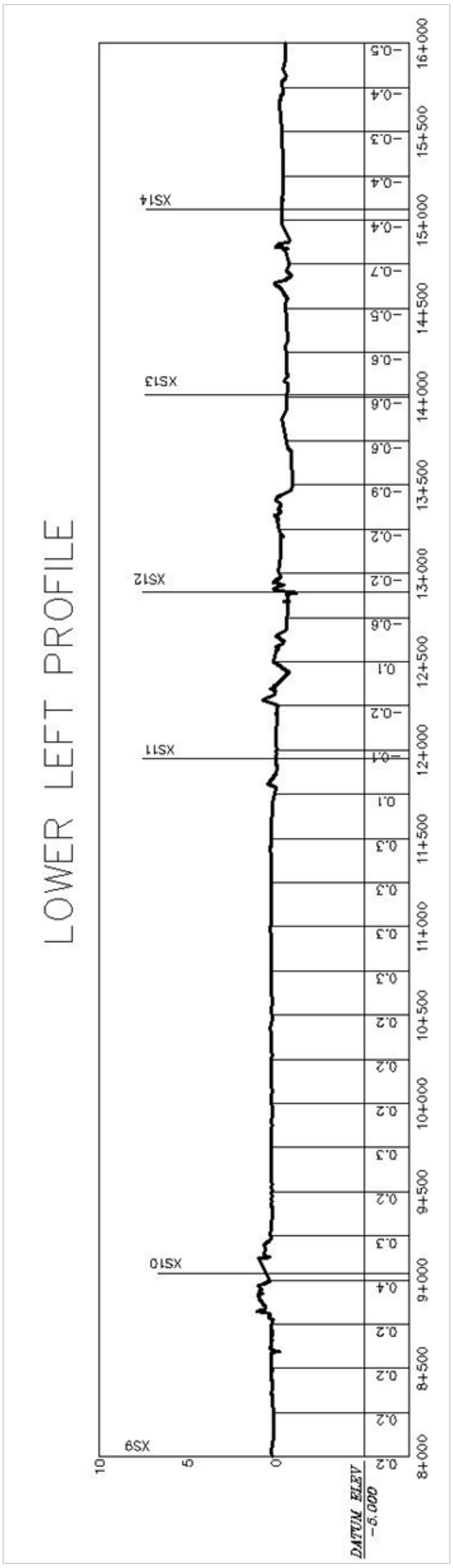

Figure 27. Lower left profile in Tagum River

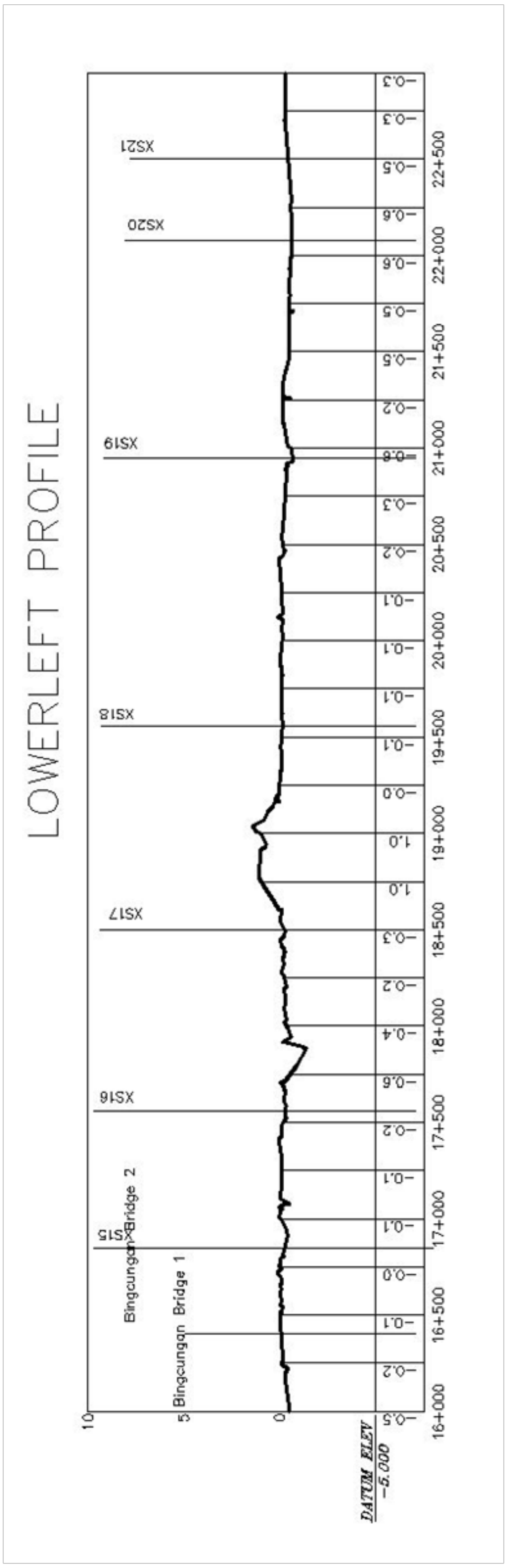

Figure 28. Lower left profile in Tagum River

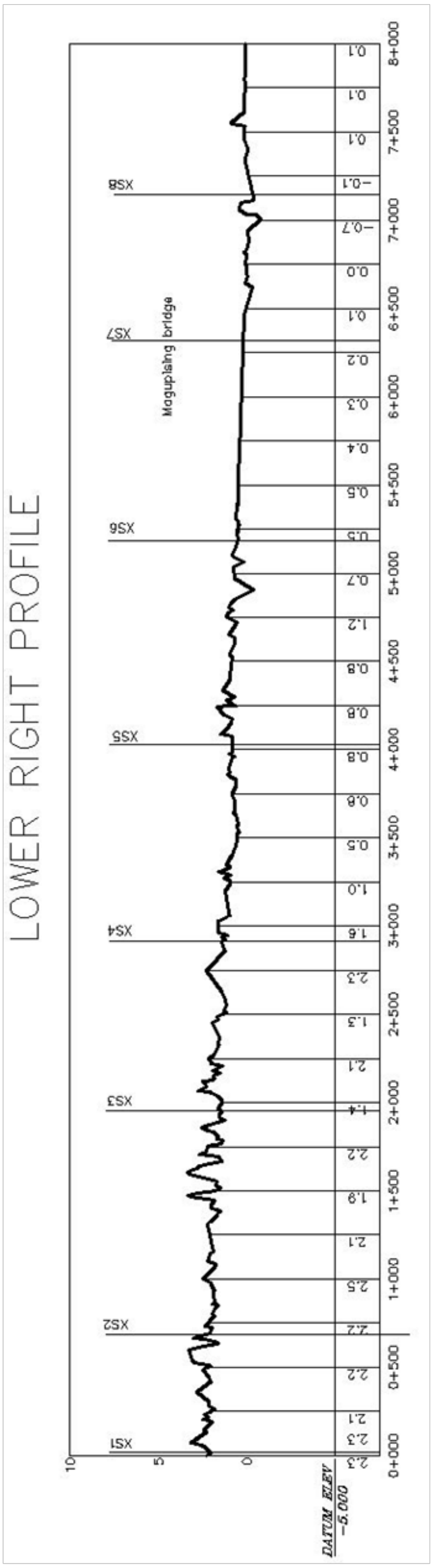

Figure 29. Lower right profile in Tagum River

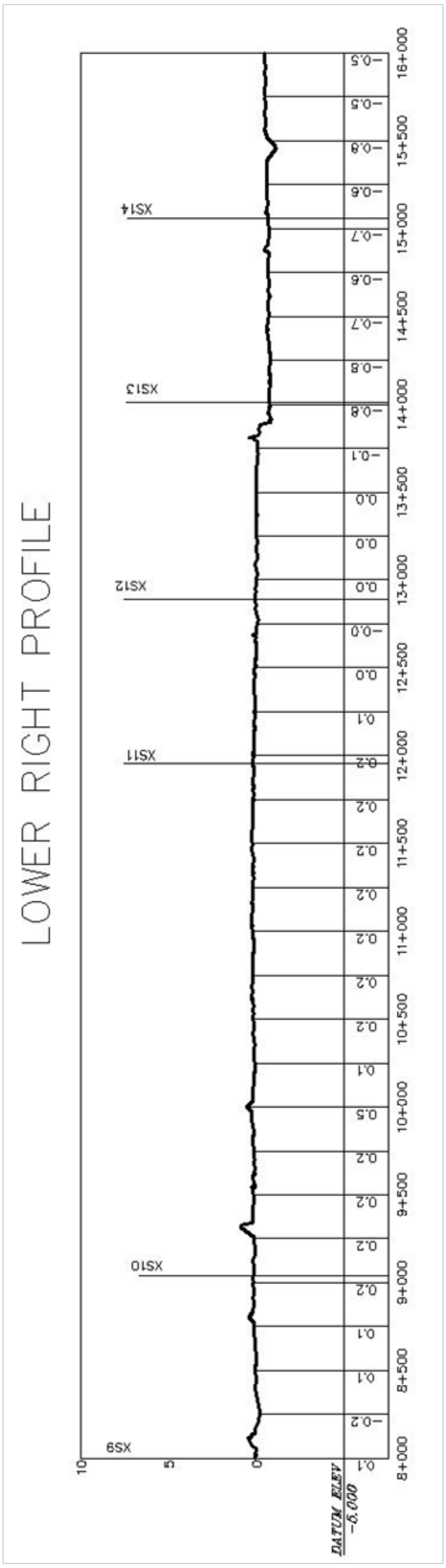

Figure 30. Lower right profile in Tagum River

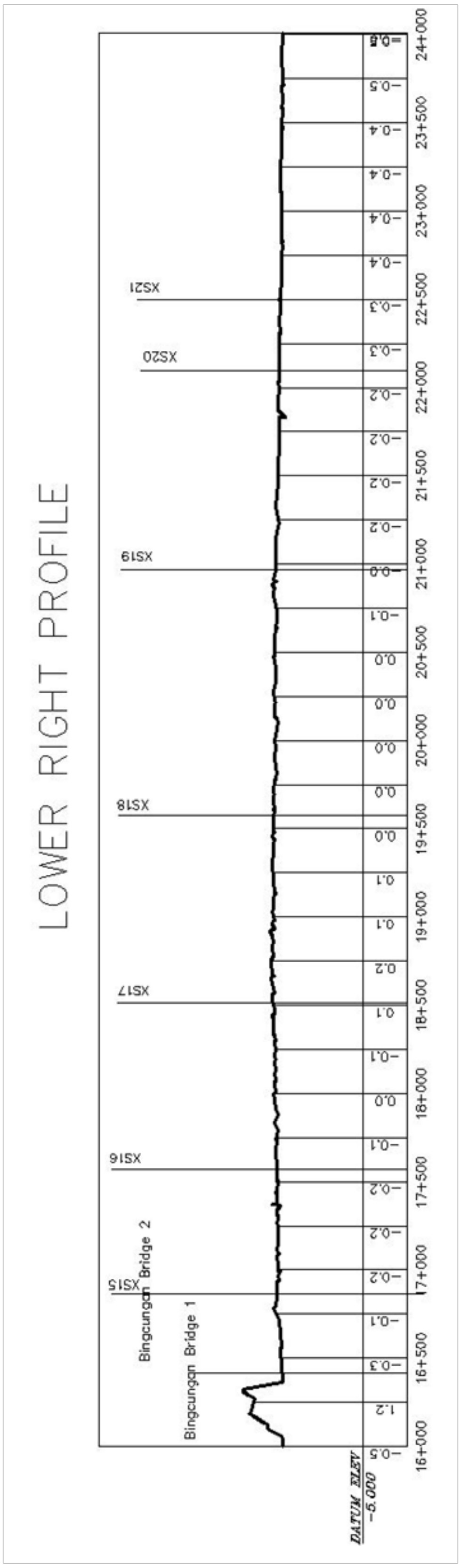

Figure 31. Lower right profile in Tagum River

4.4 Cross-section Survey

4.4.1 Cross-section along Tagum River

The topography of a river can be described using series of cross-sections that cut perpendicularly across the channel of the river. Bathymetric survey data of the river combined with ground survey data of the floodplain can produce a series of cross-sections along the stretch of the river.

Horizontal position (easting and northing) and vertical (elevation) measurements were done at a specific interval as one traverses starting from riverbank across the floodplain. Cross-section survey was done through differential kinematic GNSS surveying, either post-processed kinematic or in real-time kinematic.

Twenty-one (21) cross-section lines were planned to be surveyed but only twenty (20) were completed because XS20 is located in the island with lots of nipa and coconut trees.Figure 32 to Figure 52 show the acquired cross-section lines in Tagum River.

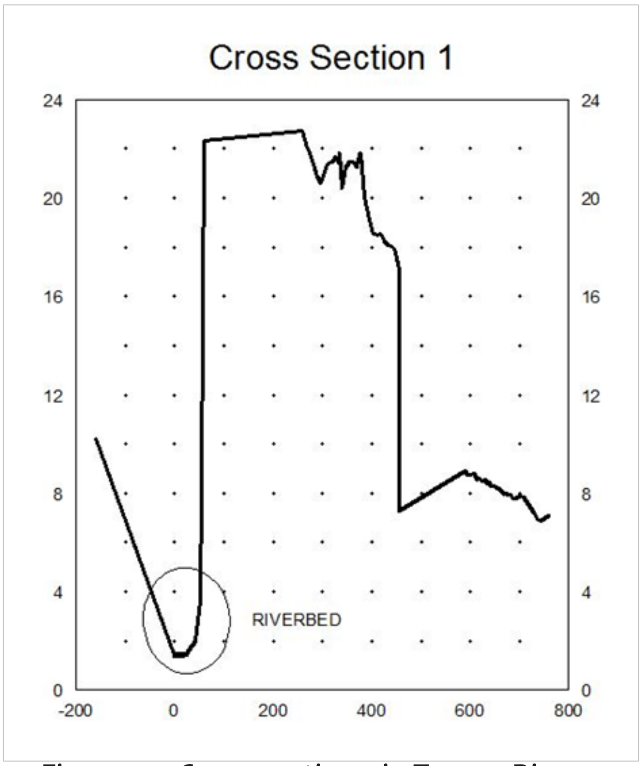

Figure 32. Cross-section 1 in Tagum River

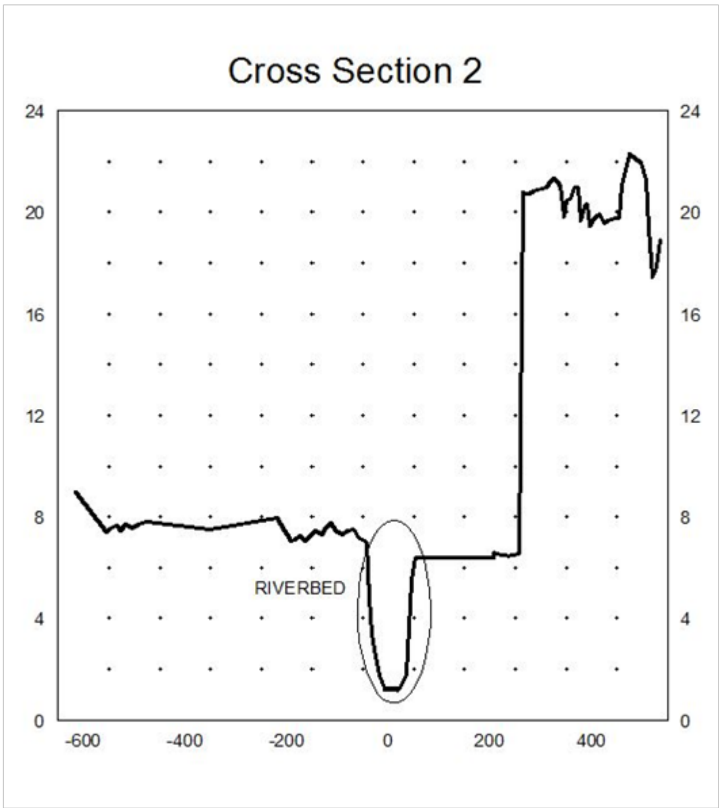

Figure 33. Cross-section 2 in Tagum River

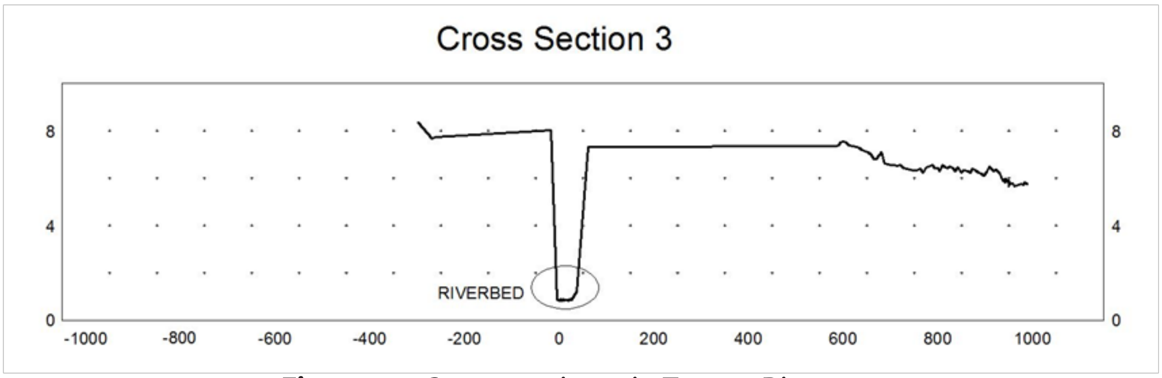

Figure 34. Cross-section 3 in Tagum River

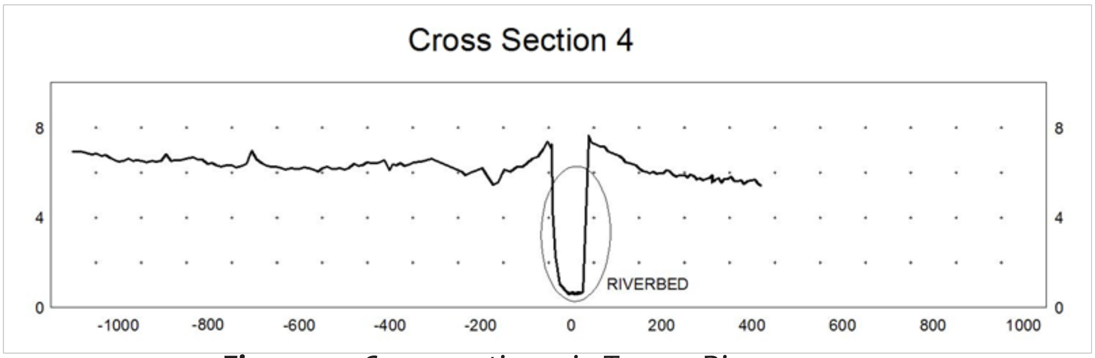

Figure 35. Cross-section 4 in Tagum River

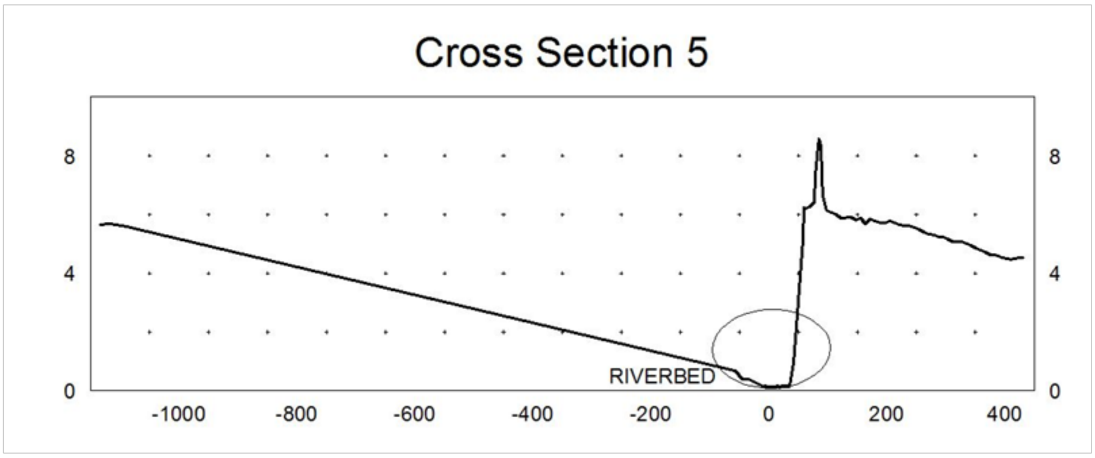

Figure 36. Cross-section 5 in Tagum River

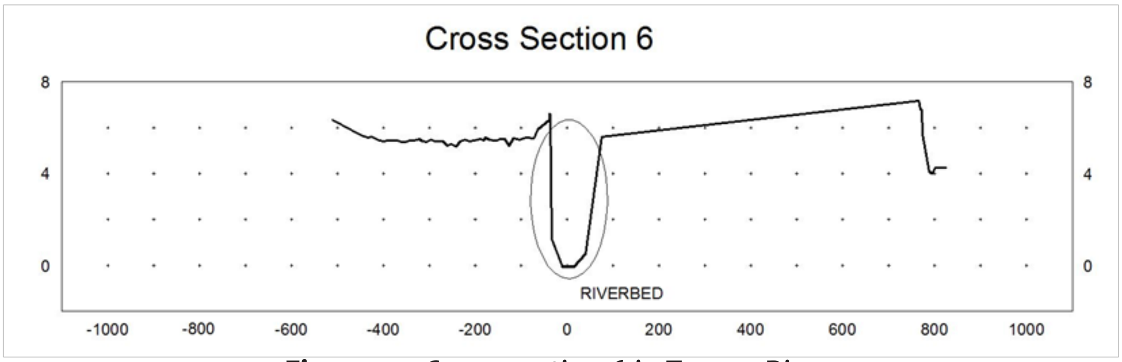

Figure 37. Cross-section 6 in Tagum River

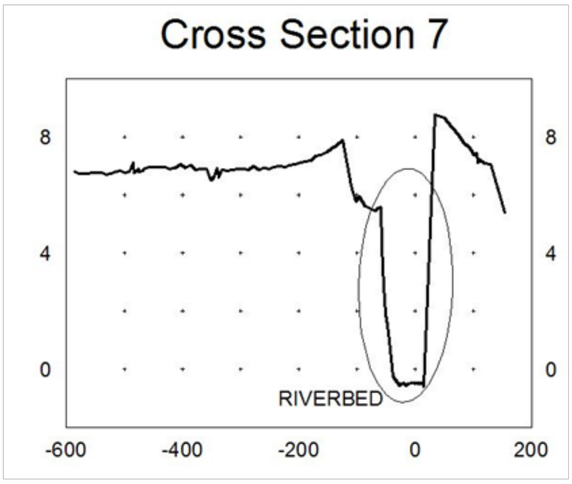

Figure 38. Cross-section 7 in Tagum River

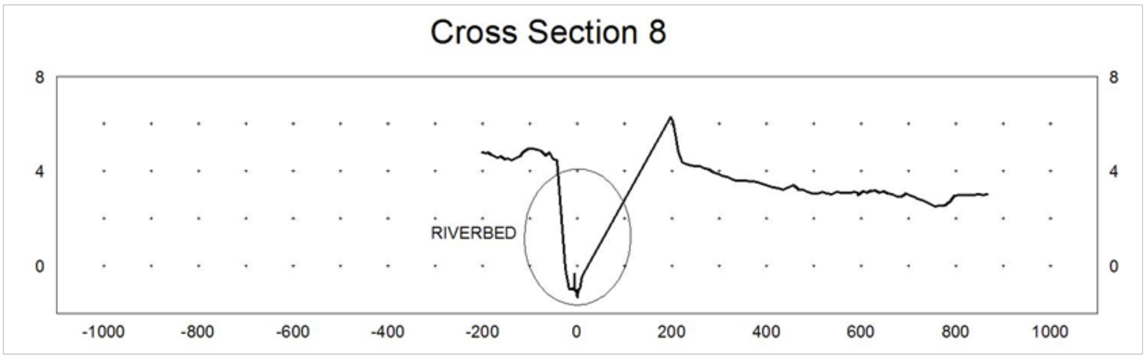

Figure 39. Cross-section 8 in Tagum River

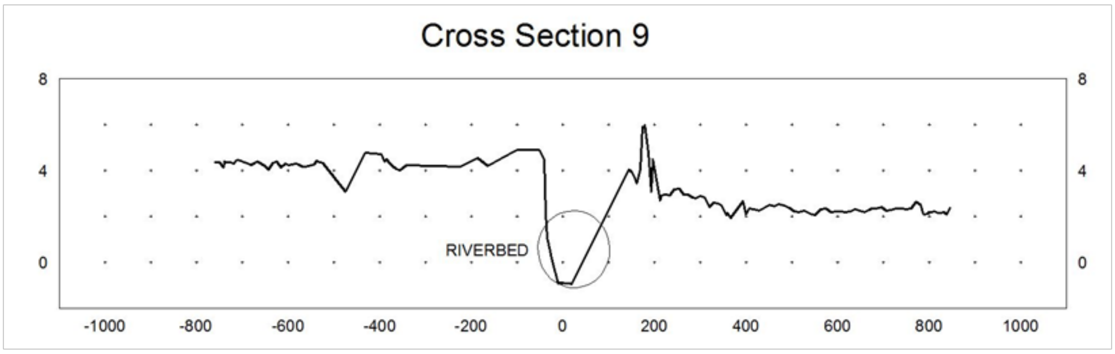

Figure 40. Cross-section 9 in Tagum River

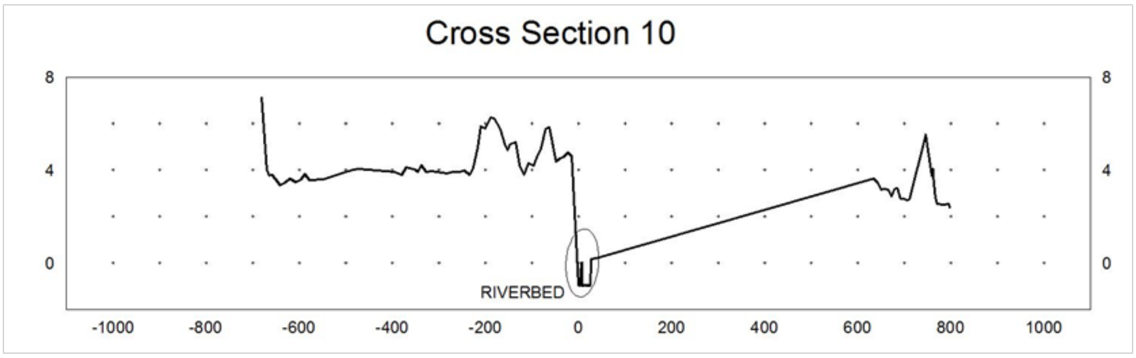

Figure 41. Cross-section 10 in Tagum River

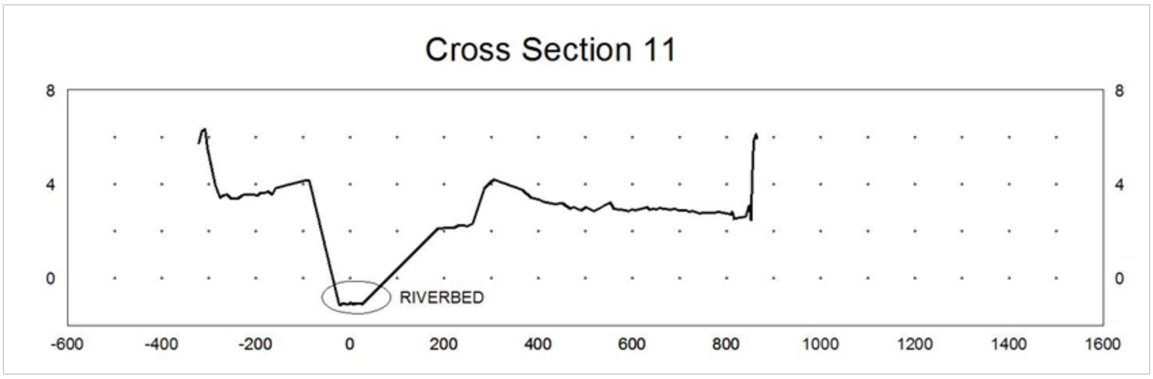

Figure 42. Cross-section 11 in Tagum River

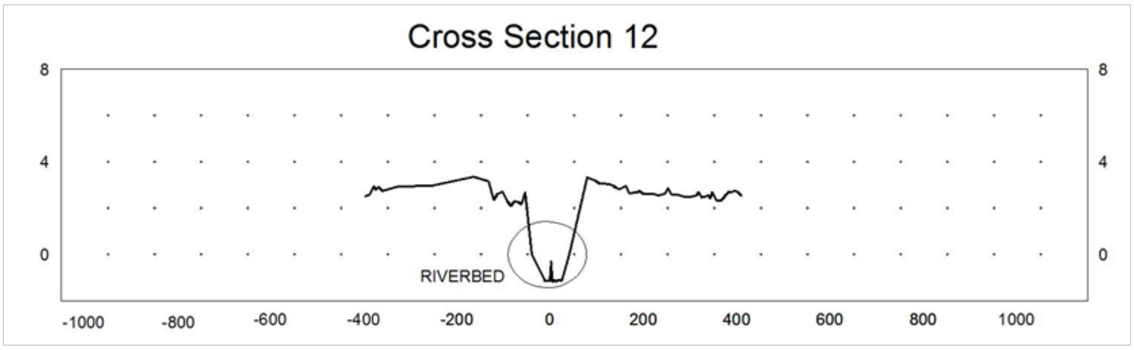

Figure 43. Cross-section 12 in Tagum River

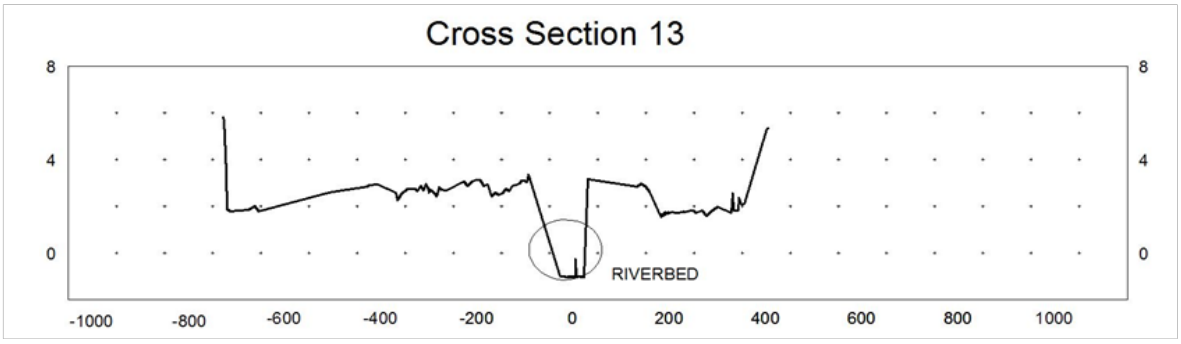

Figure 44. Cross-section 13 in Tagum River

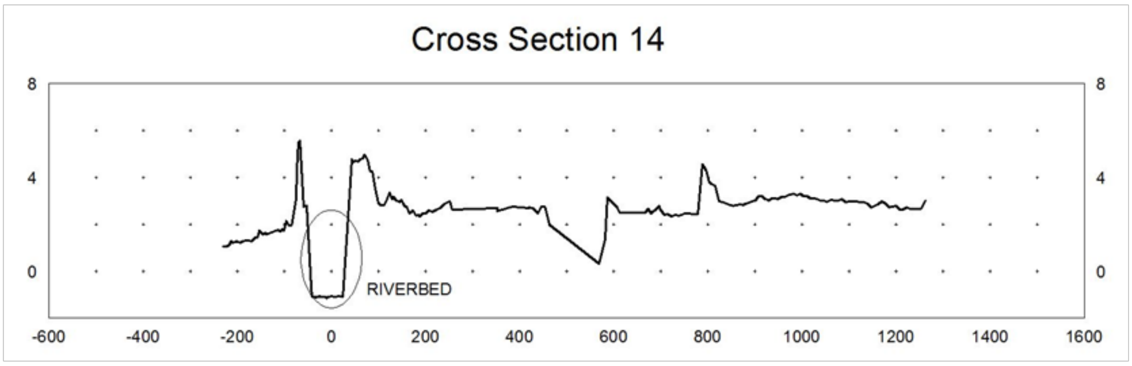

Figure 45. Cross-section 14 in Tagum River

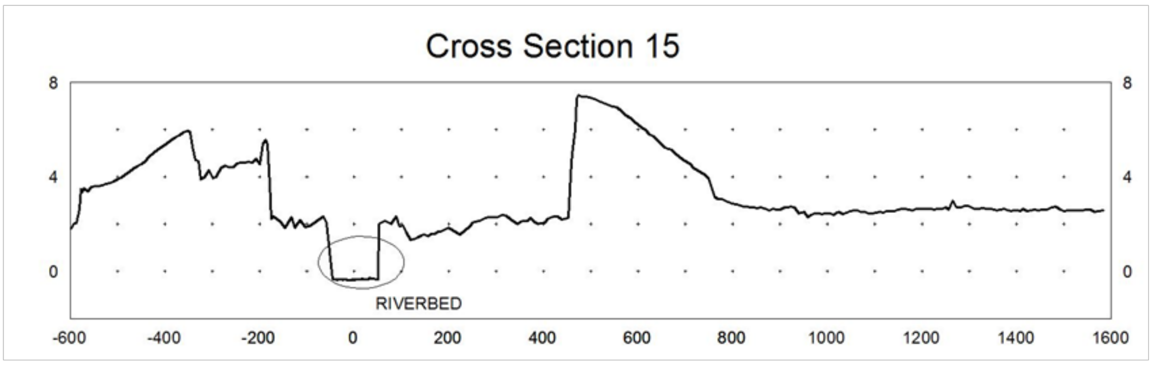

Figure 46. Cross-section 15 in Tagum River

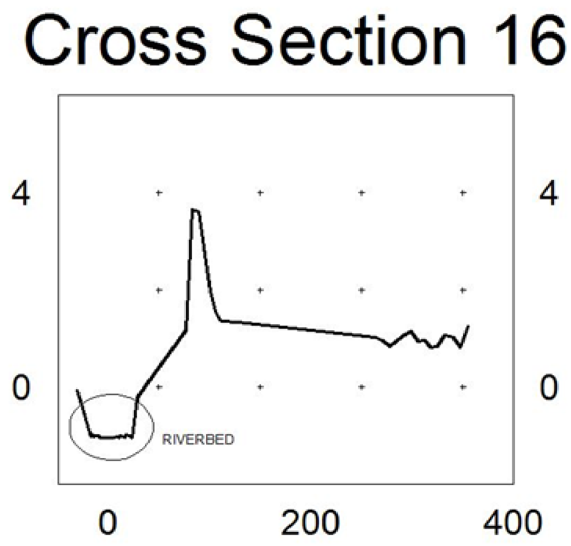

Figure 47. Cross-section 16 in Tagum River

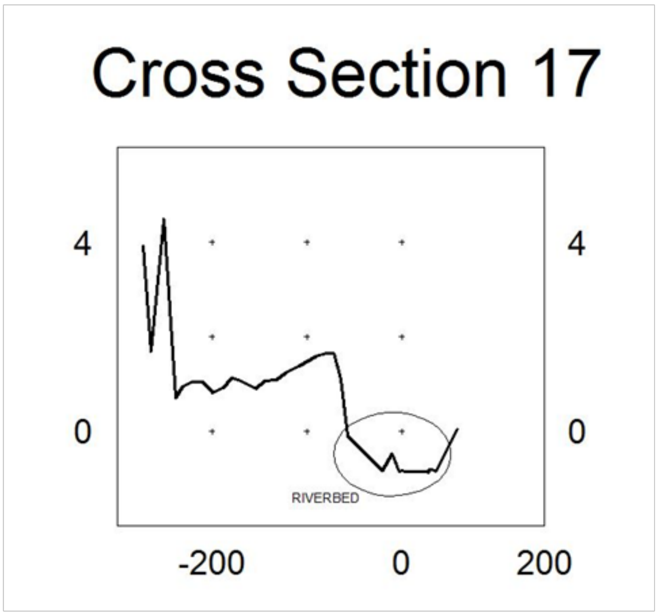

Figure 48. Cross-section 17 in Tagum River

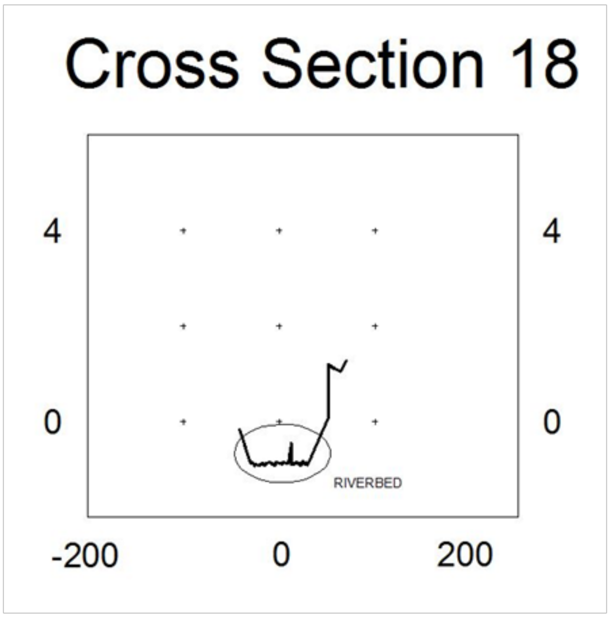

Figure 49. Cross-section 18 in Tagum River

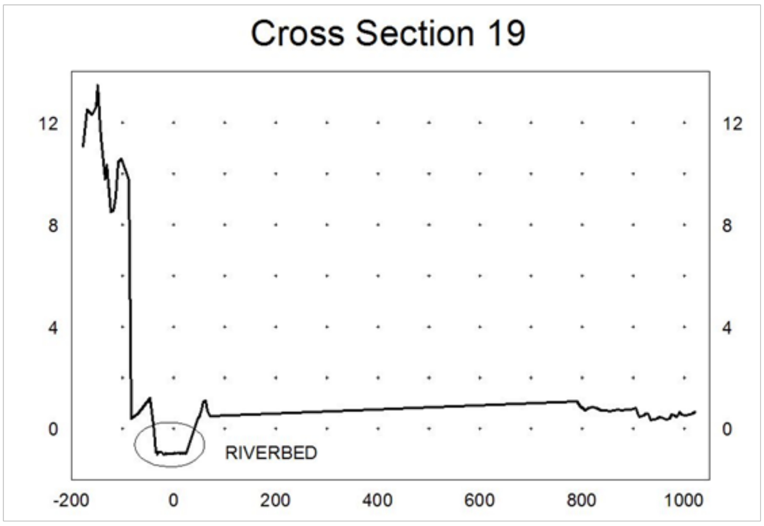

Figure 50. Cross-section 19 in Tagum River

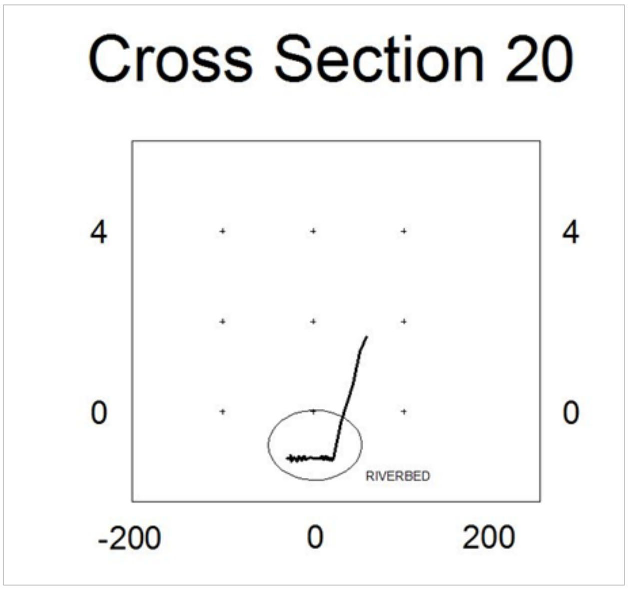

Figure 51. Cross-section 20 in Tagum River

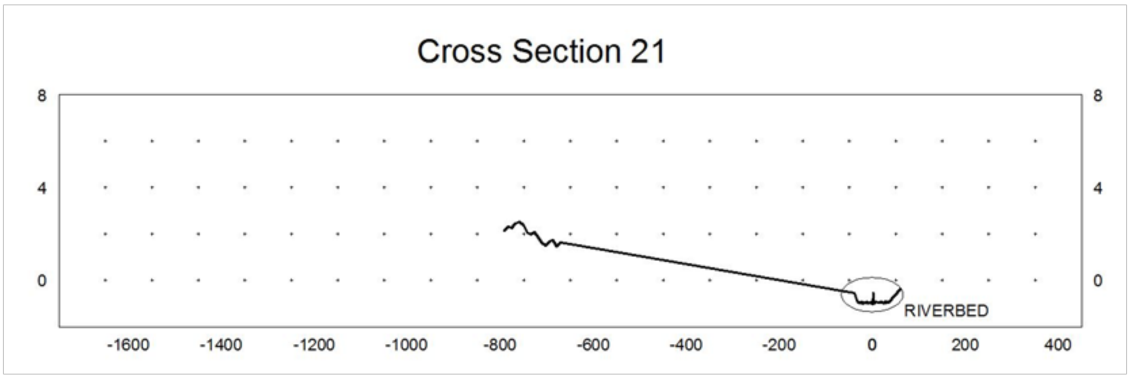

Figure 52. Cross-section 21 in Tagum River

4.4.2 Cross-section of AWLS sites in Tagum River System

Cross-section surveys were also conducted for the bridges with installed AWLS along the Tagum River System using GNSS PPK survey technique. The elevation of the installed AWLS and the water surface elevation along the banks near the sensor were acquired as well. For the cross-sections in FVR Nanaga 1 and Ilog Bridges, the survey was done on December 2013 while for ManikiBridge, the survey was on May 2014.

The location of sensors in Tagum River is shown in Figure 53. The summary of data elevation data gathered for each bridge location is summarized in Table 3.

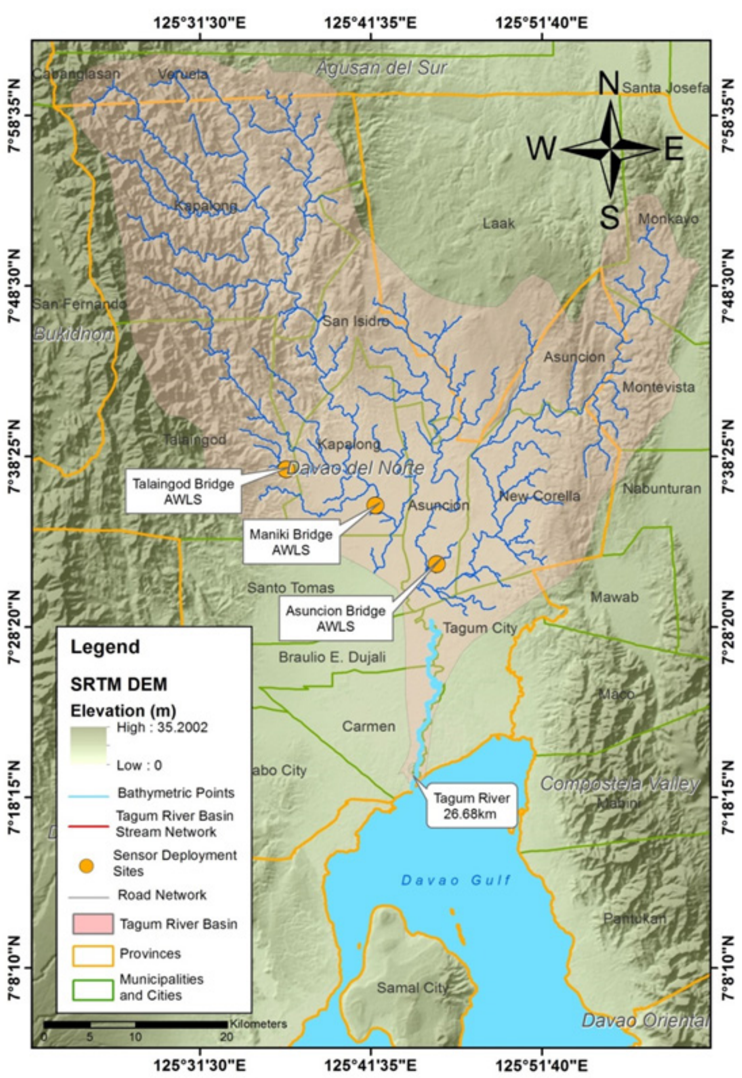

Figure 43. Cross-section 12 in Tagum River

Table 3. Location and summary of data for AWLS in Tagum River System

AWLS	Location	Coordinates	AWLS Elevation(m), in MSL	Water Surface Elevation(m), in MSL	Date& Time of Determining the Water Elevation	Image
FVR Nanaga 1 Bridge	Brgy. Sto. Niño, Municipality of Talaingod	Lat7°37'39.51" N Long 125°36'36.44" E	51.5380 m	43.9682 m	12/7/2013 12:10 PM	
Ilog Bridge	Brgy. Poblacion, Municipality of Asuncion	Lat7°32'03.37" N Long 125°45'29.39" E	17.0107 m	11.2302 m	1/18/2014 12:10 PM	
Maniki Bridge	Brgy. Pag-Asa, Municipality of Kapalong	Lat7°35'31.33" N Long 125°41'52.35" E	35.9848 m	25.7898 m	5/28/2014 03:14 PM	

The diagram of cross-section data gathered for bridges with installed AWLS is illustrated in Figure 54 to Figure 56.

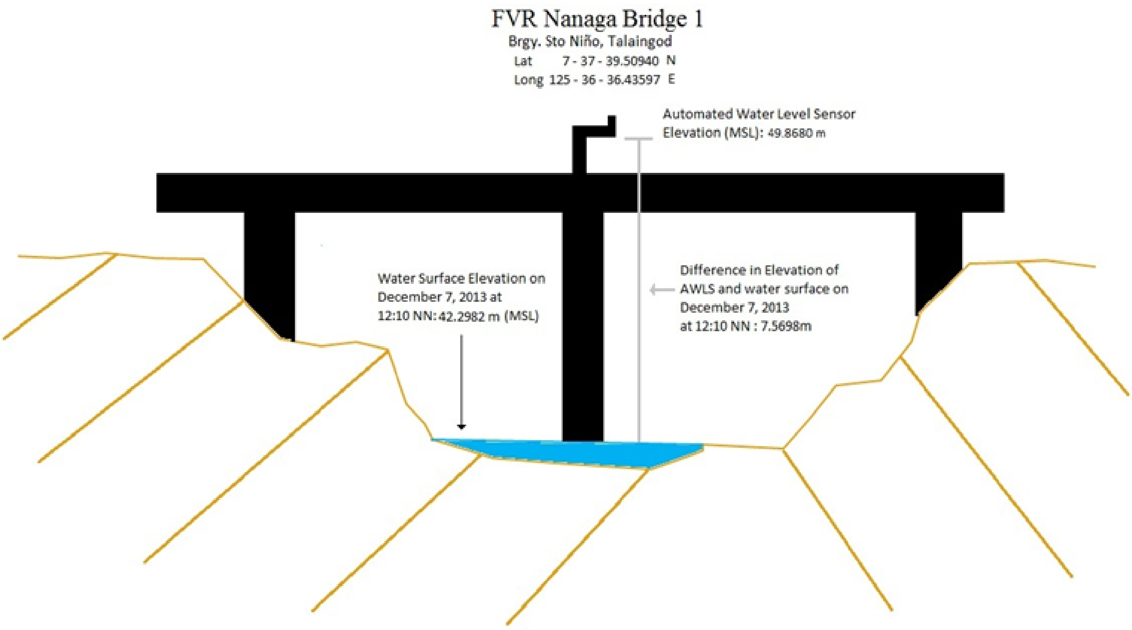

Figure 54. Cross-section diagram of FVR Nanaga Bridge 1, Brgy.Sto. Niño, Talaingod

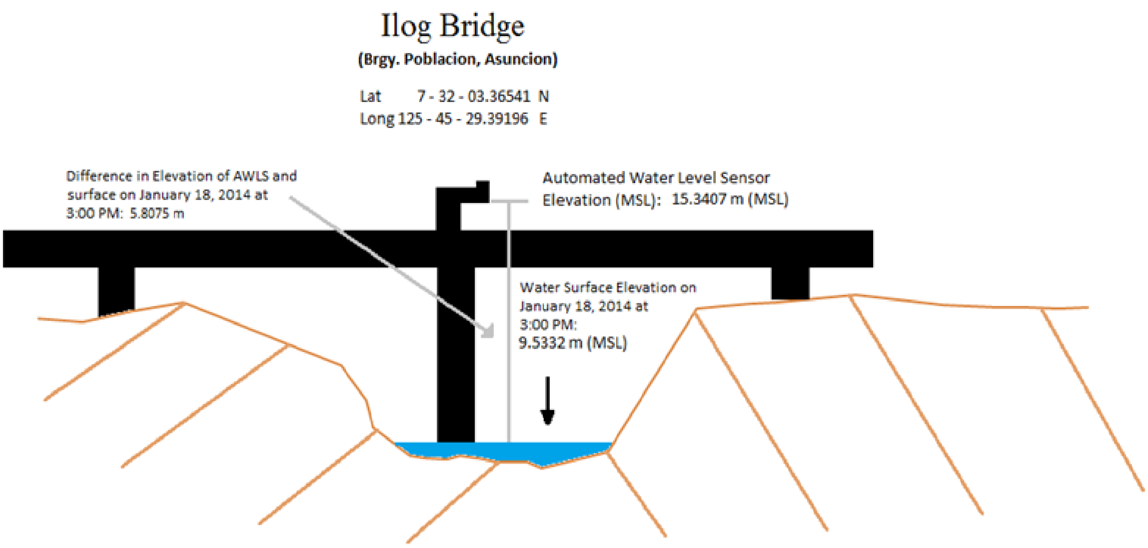

Figure 55. Cross-section diagram of Ilog Bridge, Brgy.Poblacion, Asuncion

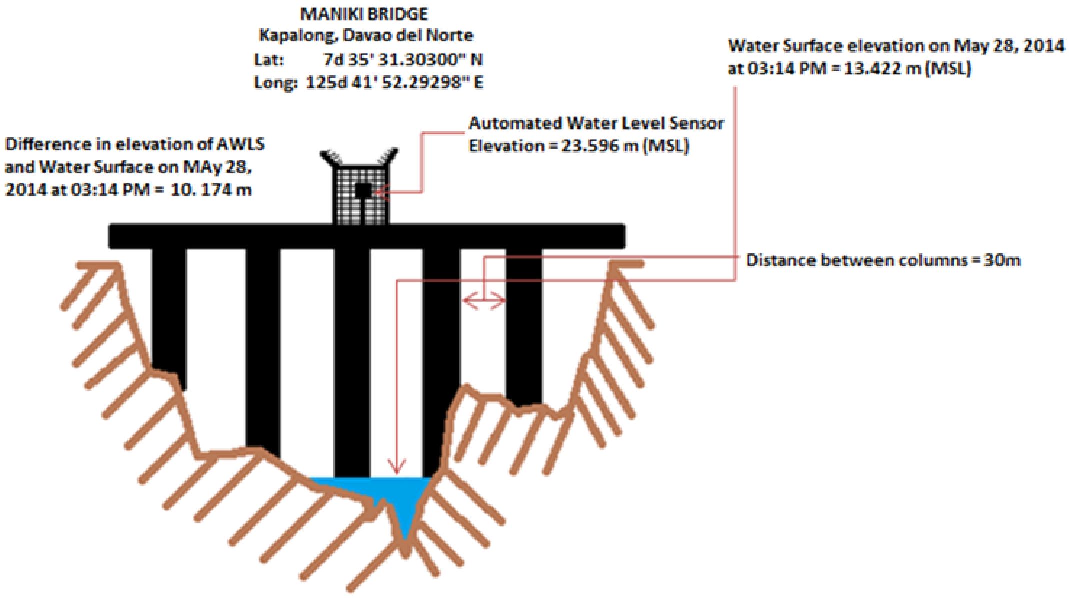

Figure 56. Cross-section diagram of Maniki Bridge,Brgy.Pag-Asa,Kapalong

4.5 Hydrometric Survey

4.5.1 Hydrometric Sensors Deployment with Stage Discharge Computation

Different sensors were deployed on the banks of Tagum River to obtain its physical characteristics such as cross-section elevation in MSL, velocity, and elevation of water level in MSL at a particular time.

Data collection in BrgyPagsabangan, Tagum City using ADCP, Depth Gauge and Rain Gauge deployment started on the 30th of April, 2013 and retrieved on the 6th of May, 2013. The ADCP was monitored and its data downloaded every two (2) days while the depth gauge which was installed on the metal frame together with the ADCP and the Rain Gauge, installed in Brgy. Pagsabanagan along Tagum River continued gathering data until its retrieval. Another depth gauge was installed at Guadalupe Bridge, Barangay Guadalupe, Municipality of Carmen, at Lat7° 7'55.98" N and Long 125°34'58.54" E. The details for the deployed sensors along Tagum River issummarized in Table 4.

The data gathered from rain gauge shows the distribution of rainfall within the observation period from April 24 to 30, 2013. Each sensor has five (5)-minute interval. The first surge of rain, which reached 1mm, was observed on April 24, 2013 at 1:35 pm. Highest amount of rain collected occurred on the 24th, 27th and 28th of April, 2013 at 2.2 mm. Relationships of data gathered within the observation period are illustrated in Figure 60 to Figure 63.

Table 4. Deployment of Sensors along Tagum River

Sensor	Location	Municipality / City	Deployment - Start	Deployment – End
ADCP	Brgy. Pagsaban-gan	Tagum	30 April 2013	06 May 2013
Rain Gauge	Brgy. Pagsaban-gan	Tagum	30 April 2013	06 May 2013
Depth Gauge	Brgy. Pagsaban-gan	Tagum	30 April 2013	06 May 2013
Depth Gauge	Brgy. Guadalupe	Carmen	01 May 2013	06 May 2013

Figure 57. ADCP and depth gauge deployed in Brgy. Pagsabangan, Tagum City

Figure 58. Rain Gauge deployed in Brgy. Pagsabangan, Tagum City

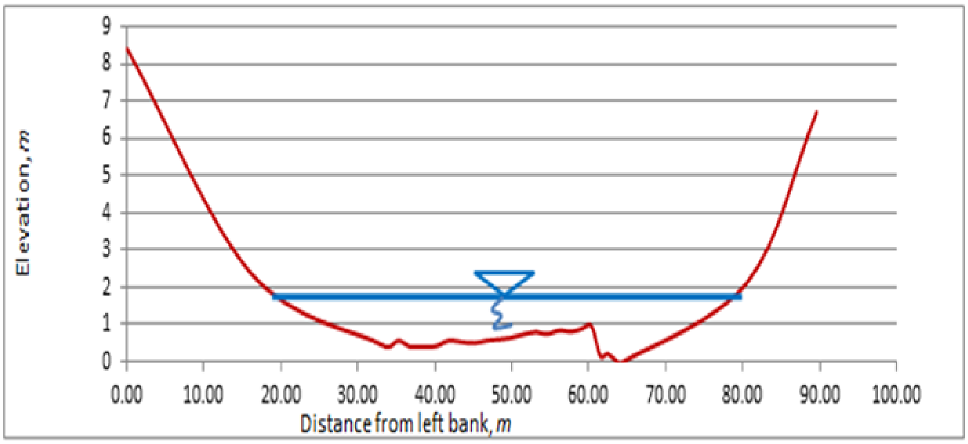

Figure 59. Graph showing the stage and cross-section along the ADCP deployment in Brgy. Pagsabangan, Tagum City

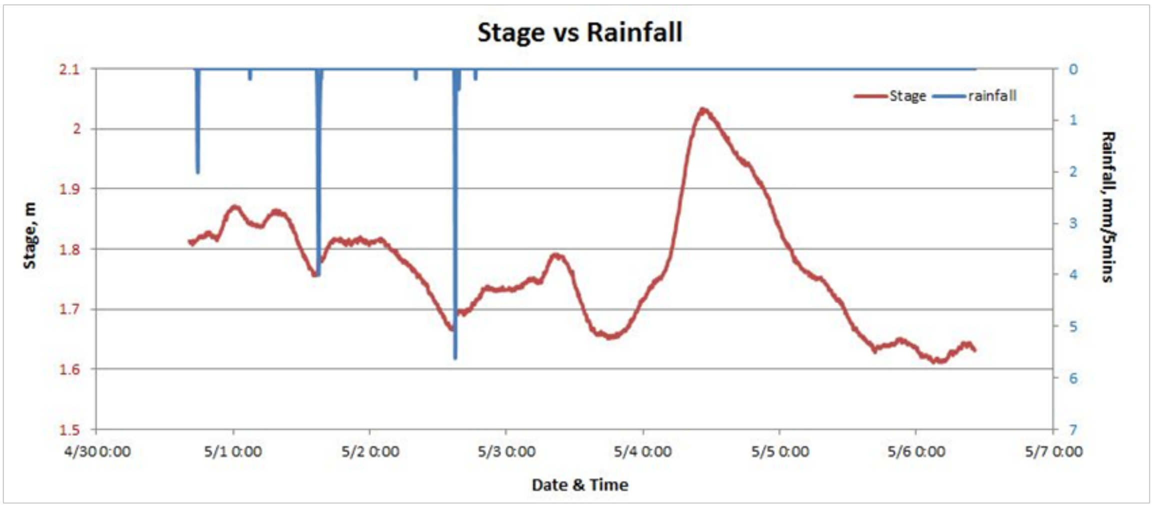

Figure 60. Relationship between stage and rainfall

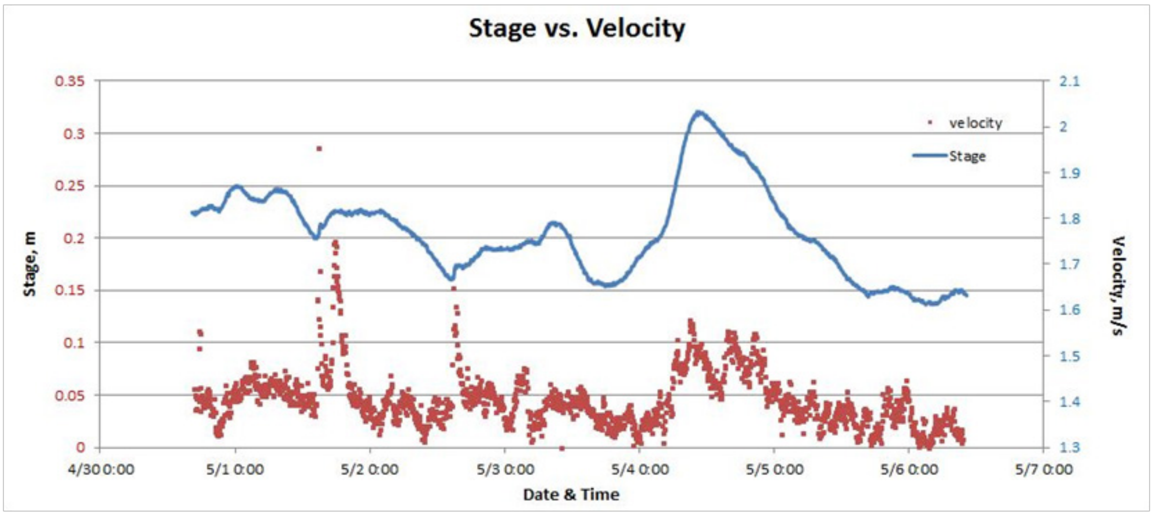

Figure 61. Relationship between velocity and stage

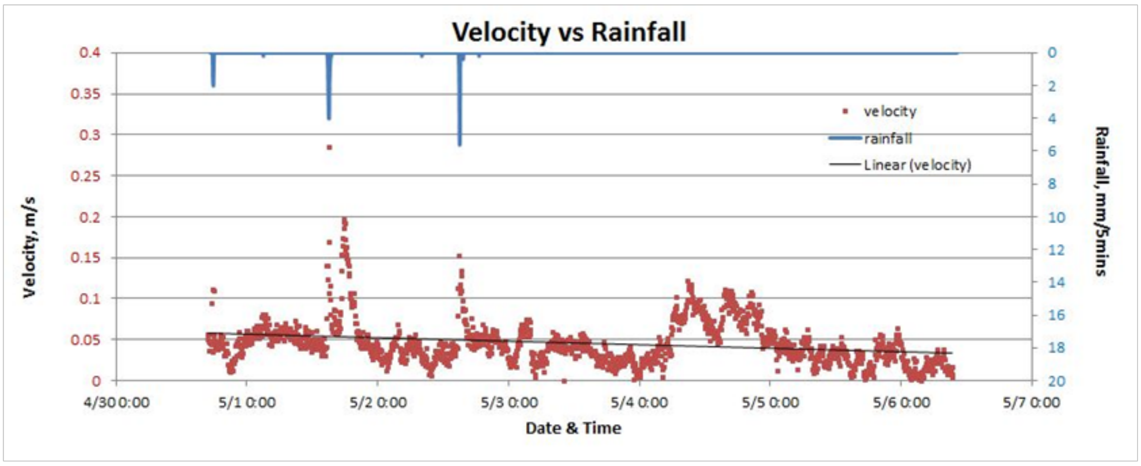

Figure 62. Relationship between velocity and rainfall

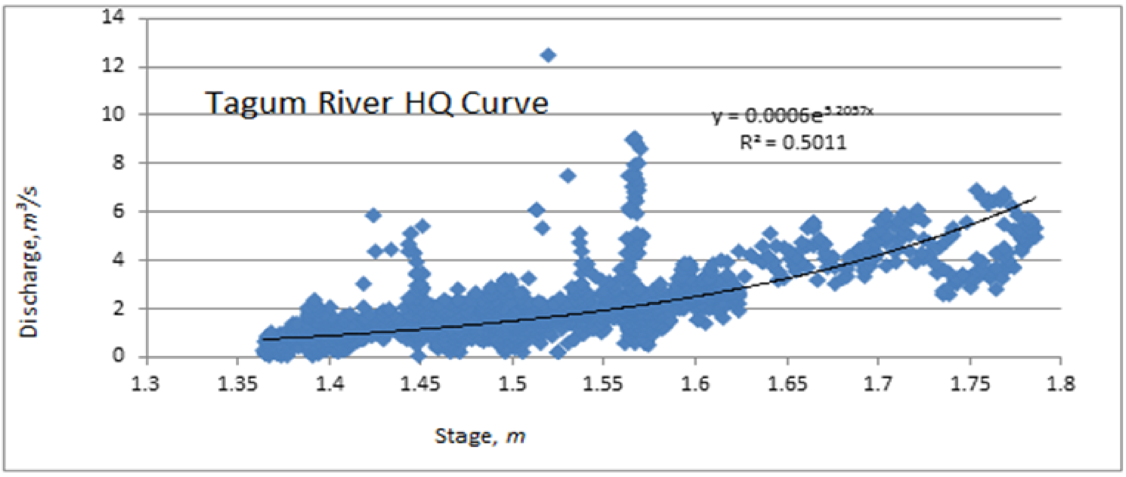

Figure 63. Relationship between stage and discharge

The relationship between the stage or water surface elevation referred to MSL and river discharge on a specific area of the river is illustrated in Figure 63. A value approaching R2 = 1 indicates a good correlation.

4.5.2 Flow Measurements and Stage Discharge Computation in AWLS Sites

Two (2) local hires living within the vicinity of the bridge were employed to gather flow measurements. Two types of events were recorded by the team – (1) base flow or the normal stream flow, without the influence of a precipitation. In this scenario, local hires were tasked to record the velocity of the river for two hours each in the morning and afternoon for a single day; and (2) the flow of the river during the occurrence of a rain event.

Two rainfall events were needed prior retrieval of the flow meters. In this type of event, the water velocity was recorded for six-hours straight while precipitation was on-going, day and night. Continuous recording of flow measurements were done until two rain events were observed. The summary of hydrometry data gathered per bridge location is summarized in Table 5.

Table 5. Summary of hydrometry data of bridges with AWLS in

Bridge	Location		Date of Deployment	Installed AWLS	Flow Measurement	Cross Section	HQ Curve
	City / Municipality	Coordinates					
FVR Nanaga Bridge I	Talaingod	Lat7⁰37'39.51" N Long 125⁰36'36.44" E	07 Dec2013	/	/	/	/
Ilog Bridge	Asuncion	Lat7⁰32'03.37" N Long 125⁰45'29.39" E	23 Nov2013	/	/	/	/
Maniki Bridge	Kapalong	Lat7⁰35'31.33" N Long 125⁰41'52.35" E	29 May 2014	/	/	/	/

A. FVR Nanaga Bridge I Stage Discharge Computation

River velocity data for FVR Nanaga Bridge I was plotted against water level data from an Automated Water Level Sensor (AWLS). Flow measurements were recorded for 43 daysfor December 7, 2013 to January 18, 2014 for three (3) hours observation. The summary of data gathered is illustrated in Figure 68 to Figure 71.

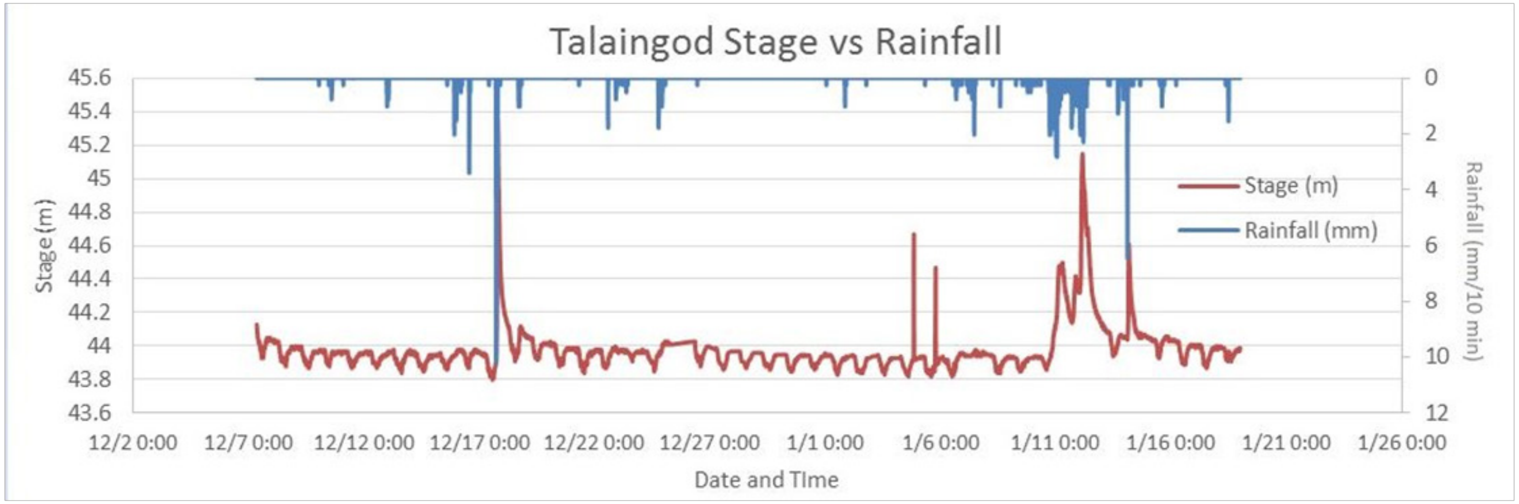

Figure 68. Stage vs. Rainfall graph in Talaingod

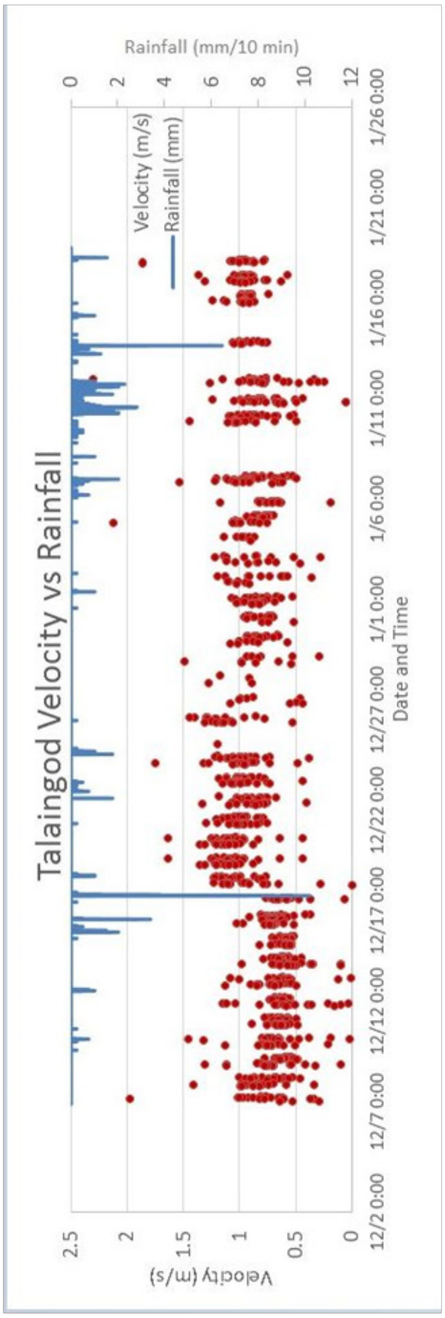

Figure 69. Velocity vs. Rainfall graph in Talaingod

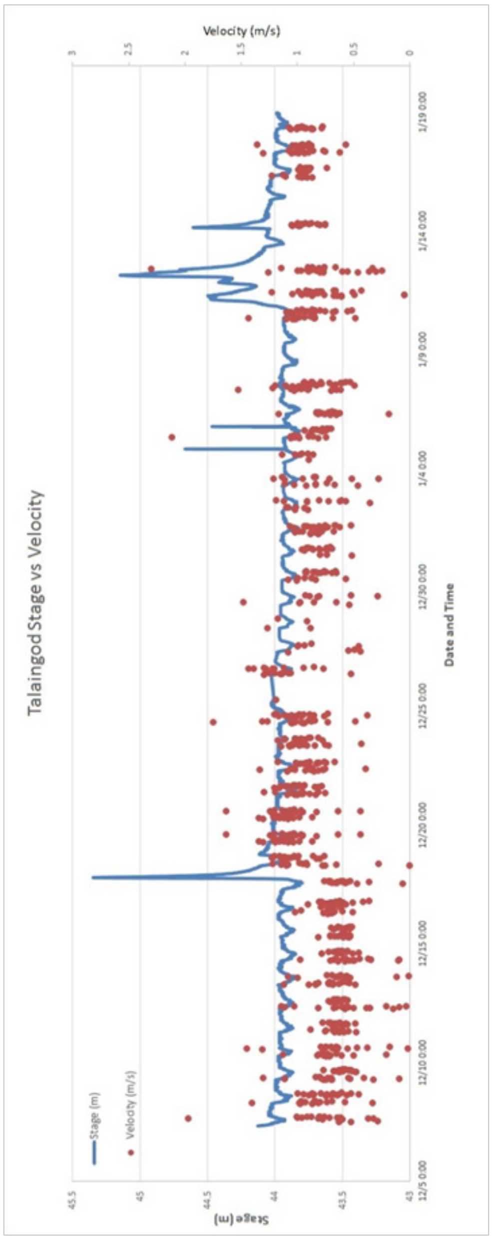

Figure 70. Stage vs. Velocity graph in Talaingod

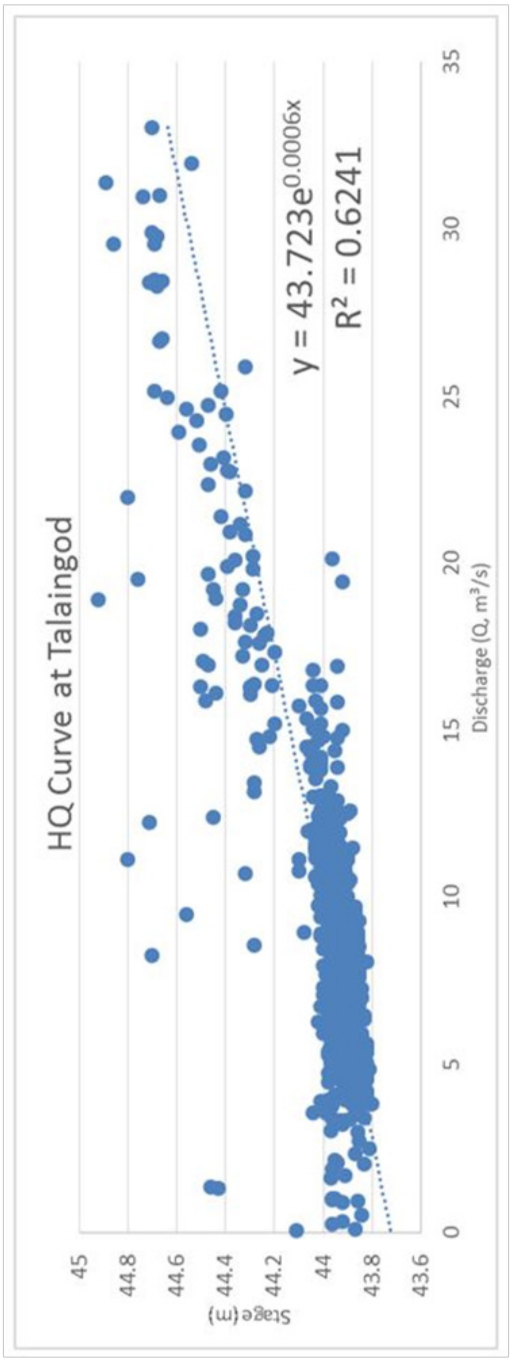

Figure 71. HQ Curve in Talaingod

B. Ilog Bridge Stage Discharge Computation

River velocity data for Ilog Bridge was plotted against water level data from an Automated Water Level Sensor (AWLS). Flow measurements were recorded for 16 days from November 23 to December 8, 2013 for three (3) hours observation. The summary of data gathered is illustrated in Figure 72 to Figure 75.

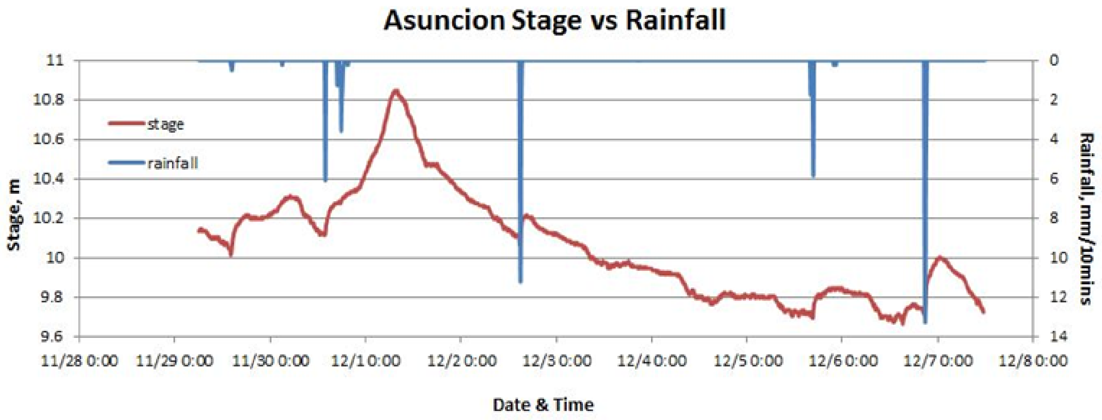

Figure 72. Stage vs. Rainfall graph in Asuncion

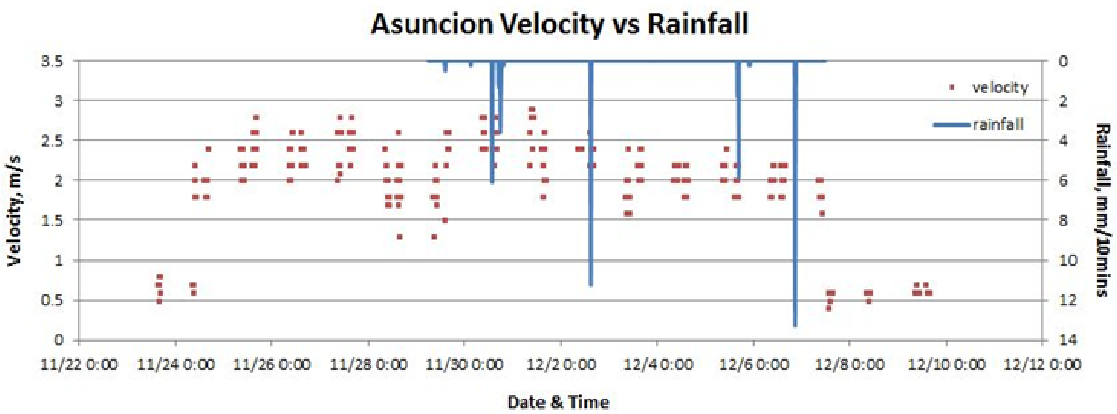

Figure 73. Velocity vs. Rainfall graph in Asuncion

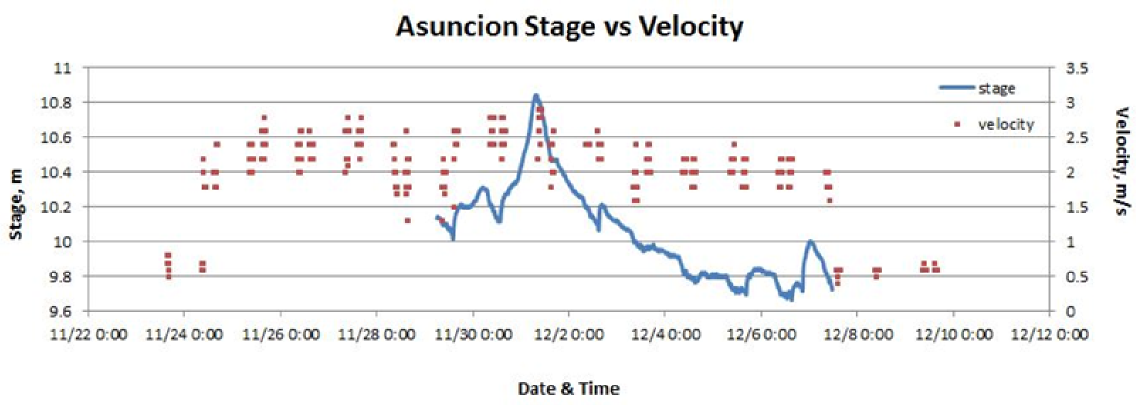

Figure 74. Stage vs. Velocity graph in Asuncion

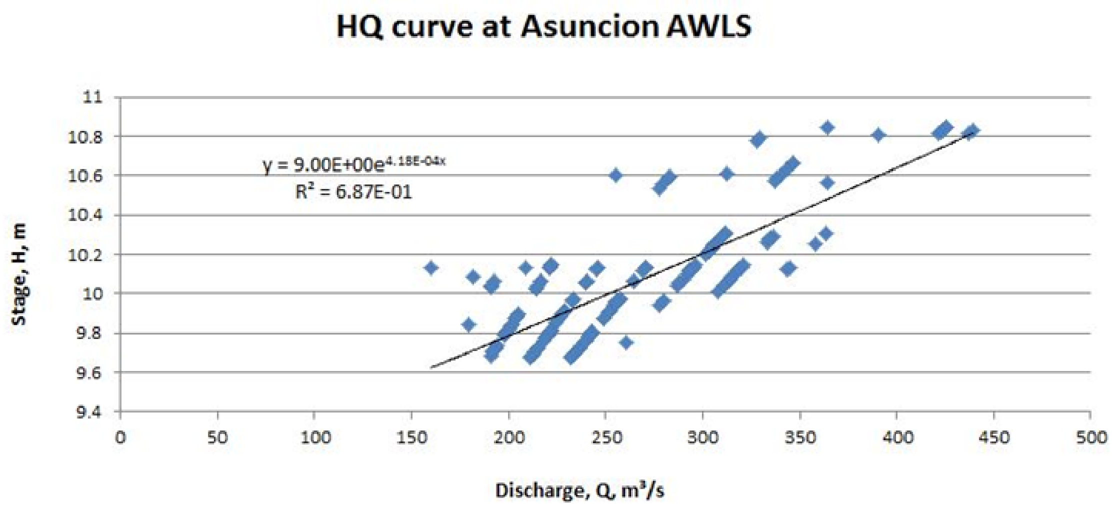

Figure 75. HQ Curve in Asuncion

C. Maniki Bridge Stage Discharge Computation

River velocity data for Maniki Bridge was plotted against water level data from an Automated Water Level Sensor (AWLS). Flow measurements were recorded for 23 days from May 29 to June 20, 2014 for three (3) hours observation. The summary of data gathered is illustrated in Figure 76 to Figure 79.

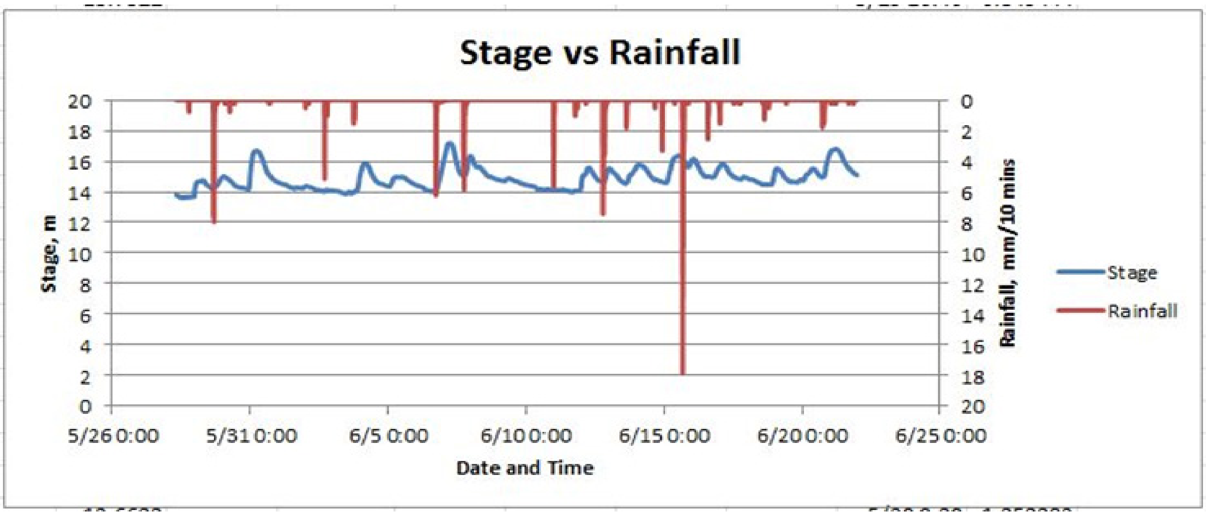

Figure 76. Stage vs. Rainfall graph in Kapalong

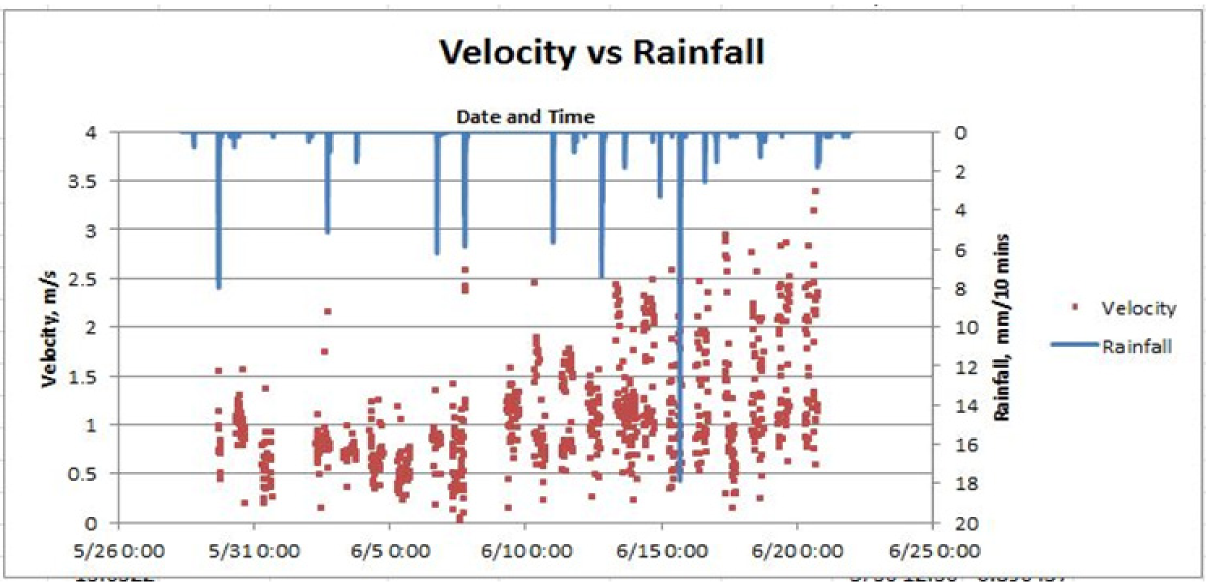

Figure 77. Velocity vs. Rainfall graph in Kapalong

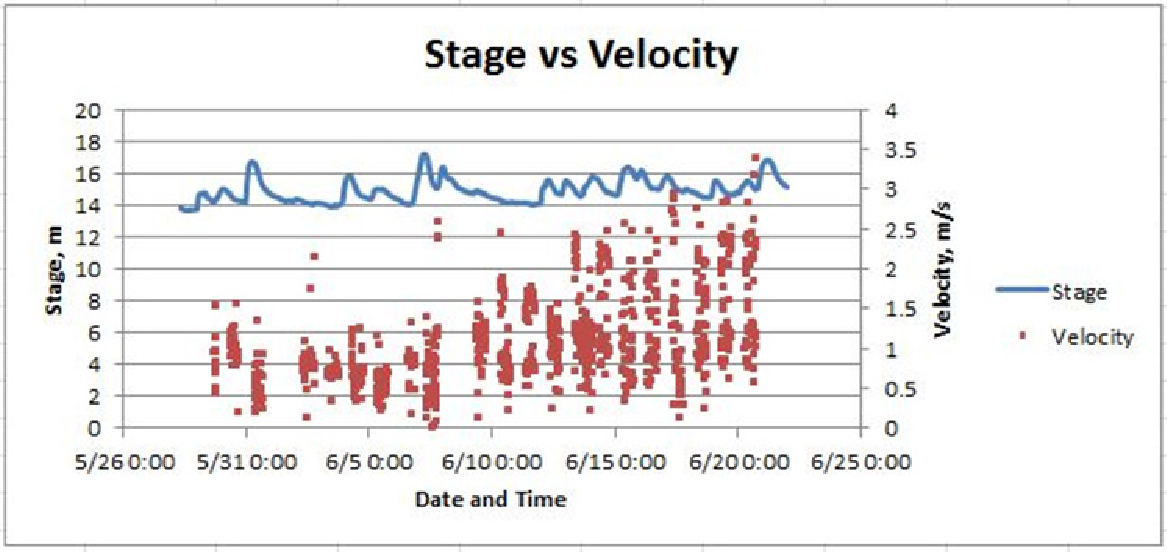

Figure 78. Stage vs. Velocity graph in Kapalong

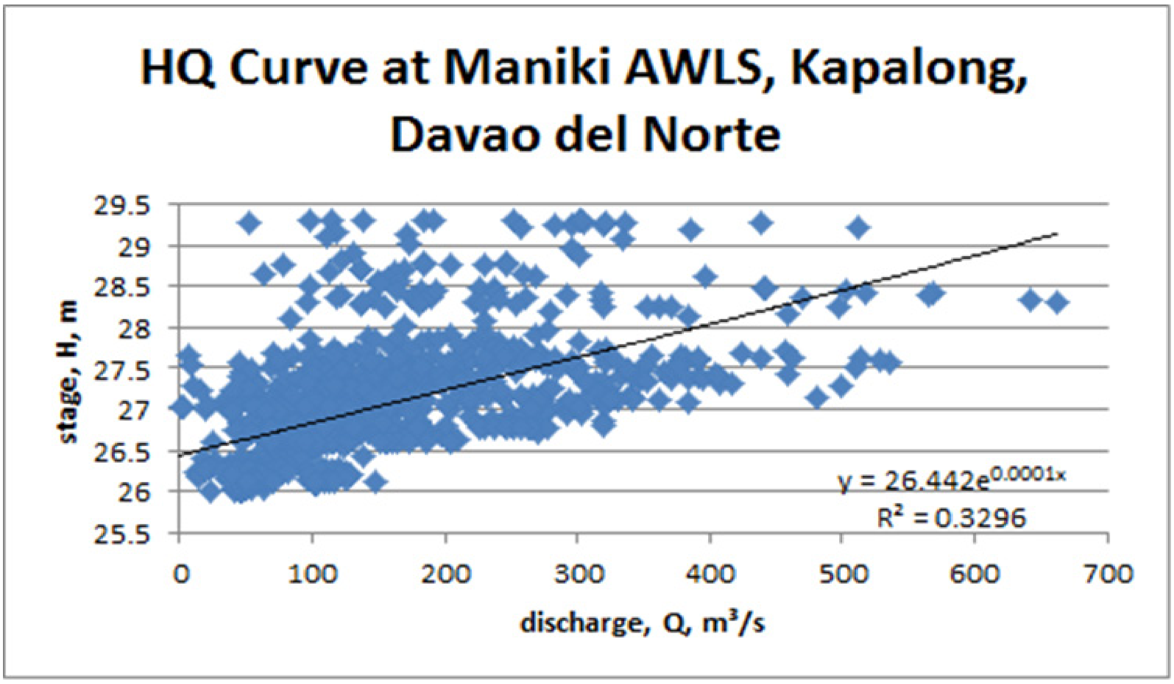

Figure 79. HQ Curve in Kapalong

Annexes

Annexes

ANNEX A. PROBLEMS ENCOUNTERED AND RESOLUTIONS APPLIED

The following shows the problems and limitations encountered during the fieldwork and the actions or solutions taken by the team.

Problems Encountered	Remarks	Solutions Applied
The team was unable to follow the straight paths along the planned cross-sections due to nipa and coconut trees.		Alternate paths were taken parallel to the cross-sections.
Sensor at Asuncion was offline during the time of water surface elevation measurement last December 8, 2013.	The team were not able to compute for the stage.	The team measured the water surface elevation again on January 18, 2014 during the retrieval of the flow meter deployed at Talaingod.
Data from the website repo.pscigrid.gov.ph for the water level sensors in Talaingod and Asuncion were intermittent. Flow data gathered by DREAM-DVC must have a corresponding water level data from the sensor.	There were days where flow data was discarded because of the missing water level data from its sensor.	The team called the attention of DOST Region 11 regarding this. This was done to ensure that the sensor will be online for the water surface elevation measurement on January 18, 2014.

ANNEX B. LIST OF EQUIPMENT AND INSTRUMENTS

Type	Brand	Owner	Quantity
GNSS Receiver (Base)	Trimble SPS852	UP-TCAGP	Three (3) units
GNSS Receiver (Rover)	Trimble SPS882	UP-TCAGP	Six (6) units
GNSS Controller	Trimble TSC3	UP-TCAGP	Six (6) units
High-Gain Antenna		UP- TCAGP	Three (3) units
RTK radio and antenna		UP-TCAGP	One (1) unit with battery
Singlebeam Echosounder	Hi-Target	UP-TCAGP	One (1) unit with accessories
Singlebeam Echosounder	Ohmex™ Echosounder	UP-TCAGP	One (1) unit with accessories
Acoustic Doppler Current Profiler (ADCP)	SonTek	UP- TCAGP	One (1) unit with accessories
Coupler-2B		UP- TCAGP	One (1) unit
Handheld GNSS	Montana 650	UP-TCAGP	Six (6) units
Laptops	Lenovo	UP-TCAGP	One (1) unit
	DellLatitude		Five (5) unit
	Panasonic Tough book (MDL)		One (1) unit
Depth Gauge	Onset Hobo wares	UP-TCAGP	Four (4) units
Rain Gauge		UP- TCAGP	Two (2) unit
Tripod	Trimble	UP-TCAGP	Three (3) units

ANNEX B. LIST OF EQUIPMENT AND INSTRUMENTS

Type	Brand	Owner	Quantity
Bipod	Trimble	UP-TCAGP	Six (6) units
Tribrach		UP-TCAGP	Three (3) unit
Laser Range Finder	Bushnell	UP-TCAGP	Two (2) units
Installers	SonTek	UP-TCAGP	One (1) unit
	Topcon		One (1) unit
	Trimble Business Center		One (1) unit
	Trimble Realworks		One (1) unit
Mobile Mapping Scanner (MMS)	MDL Dynascan	UP-TCAGP	One (1) unit with dual-GNSS antenna, one (1) interface adapter and accessories
Toolbox		UP-TCAGP	One (1) unit

ANNEX C. THE SURVEY TEAM

Data Validation Component	Designation	Name	Agency/Affiliation
	Project Leader	ENGR. LOUIE P. BALICANTA	UP TCAGP
Survey Coordinator	Chief Science Research Specialist (CSRS)	ENGR. JOEMARIE S. CABALLERO	UP TCAGP
Bathymetric Survey Team	Senior Science Research Specialist	ENGR. DEXTER T. LOZANO	UP TCAGP
	Research Associate	ENGR. JMSON J. CALALANG	UP TCAGP
Profile Survey Team	Senior Science Research Specialist	ENGR. BERNARD PAUL D. MARAMOT	UP TCAGP
	Senior Science Research Specialist	ENGR. MELCHOR REY M. NERY	UP TCAGP
Cross Section Survey Team and Sensors Deployment Team	Research Associate	JELINE M. AMANTE	UP TCAGP
	Research Associate	PATRIZCIA MAE P. DELACRUZ	UP TCAGP
	Research Associate	JOJO E. MORILLO	UP TCAGP
	Research Associate	ENGR. MARK LESTER D. ROJAS	UP TCAGP
	Research Associate	ENGR. EDJIE M. ABALOS	UP TCAGP
	Research Associate	MICHAEL ANTHONY C. LABRADOR	UP TCAGP
	Research Associate	MAX HENRY P. AFICIAL	UP TCAGP

ANNEX D. NAMRIA CERTIFICATION

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

June 11, 2013

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 NORTE**
Station Name: **DV-76**

Island: **Mindanao**	Municipality: **CARMEN**	Barangay: **TUGANAY**
Elevation: **8.3592 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

DV-76 is in the Province of Davao del Norte, City of Carmen, Barangay Tuganay taking the national highway until reaching the Gov. Miranda Bridge. Station is located at the NE abutment of Gov. Miranda at Kilometer Post KM. 1466+881.

Station mark is the head of 4" copper nail set on a drilled hole and cemented flushed on top of a 15x15cm. cement putty with inscriptions "DV-76, 2007 NAMRIA."

Requesting Party:	**UP-TCAGP DREAM**
Pupose:	**Reference**
OR Number:	**3943775B**
T.N.:	**2013-0563**

RUEL DM. BELEN, MNSA
Director, Mapping and Geodesy Department

9906112013150546

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

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

April 26, 2013

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-1**
Order: **1st**

Island: **MINDANAO**
Municipality: **DAVAO CITY**
Barangay: **TOWN PROPER**

PRS92 Coordinates

Latitude: **7° 4' 41.48387"**	Longitude: **125° 37' 31.24815"**	Ellipsoidal Hgt: **-4.50700 m.**

WGS84 Coordinates

Latitude: **7° 4' 38.36201"**	Longitude: **125° 37' 36.77094"**	Ellipsoidal Hgt: **68.27510 m.**

PTM Coordinates

Northing: **782663.345 m.**	Easting: **569084.935 m.**	Zone: **5**

UTM Coordinates

Northing: **783,162.17**	Easting: **790,026.11**	Zone: **51**

Location Description

DVS-1
From Davao City hall travel southeast along San Pedro street for 400 meters. Upon reaching the "T" intersection of San Pedro street and Quezon boulevard travel for 2.1 kms. up to the cross intersection of roads at Monteverde street, Leon Garcia street and Quezon boulevard. From this intersection turn right to Sta. Ana pier. The station is located on the east side of the new pier; 94 meters Northeast of coast guard house and north of the old pier. Station mark is 0.15 m x 0.01 m in diameter brass rod with cross cut on top, set in a drill hole, centered in a 30 cm x 30 cm cement patty on top of concrete pavement of wharf. Inscribed on top with the station name. All reference marks are 0.15 m x 0.01 m in diameter brass rods with cross cut on top, set in drill holes, centered in cement patty on concrete pavement of wharf. Inscribed on top with the reference mark numbers and arrow pointing to the station.

Requesting Party:	**UP-TCAGP**
Pupose:	**Reference**
OR Number:	**3943584 B**
T.N.:	**2013-0366**

RUEL DM. BELEN, MNSA
Director, Mapping and Geodesy Department

9904262013163513

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

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DREAM

Disaster Risk and Exposure Assessment for Mitigation