REGION 10

Cagayan de Oro River:

DREAM Ground Surveys Report

TRAINING CENTER FOR APPLIED GEODESY AND PHOTOGRAMMETRY

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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
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
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
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 river basins 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 updated 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 geospatial 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.

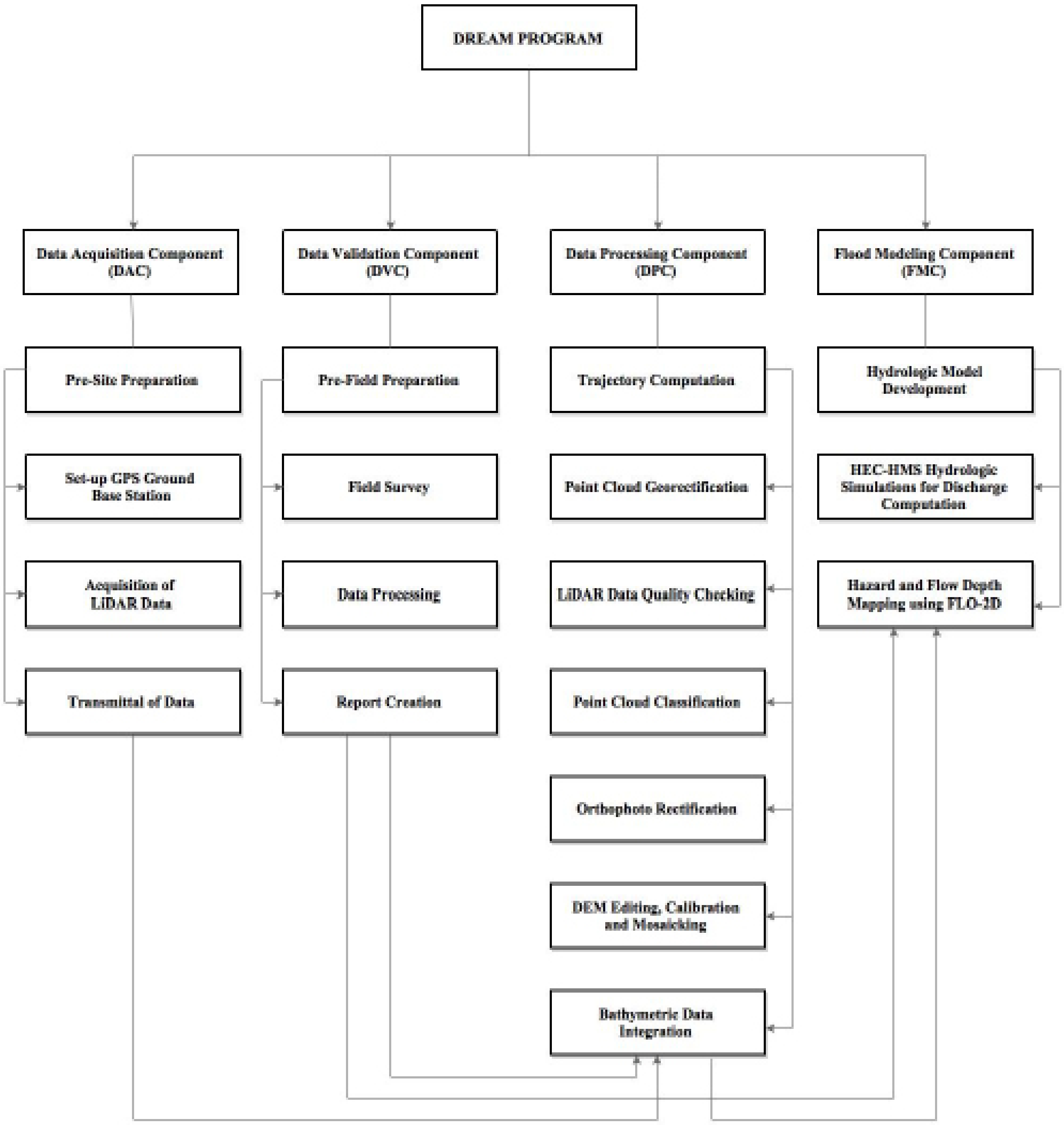

Figure 1. The General Methodological Framework of the Program

The Cagayan de Oro River Basin

The Cagayan de Oro River Basin

The Cagayan de Oro (CDO) River Basin is located in the northern coast of Mindanao. The CDO River Basin is the sixteenth largest river basin in the Philippines with an estimated basin area of 1,521 square kilometers. The location of the Cagayan de Oro River Basin is as shown in Figure 2.

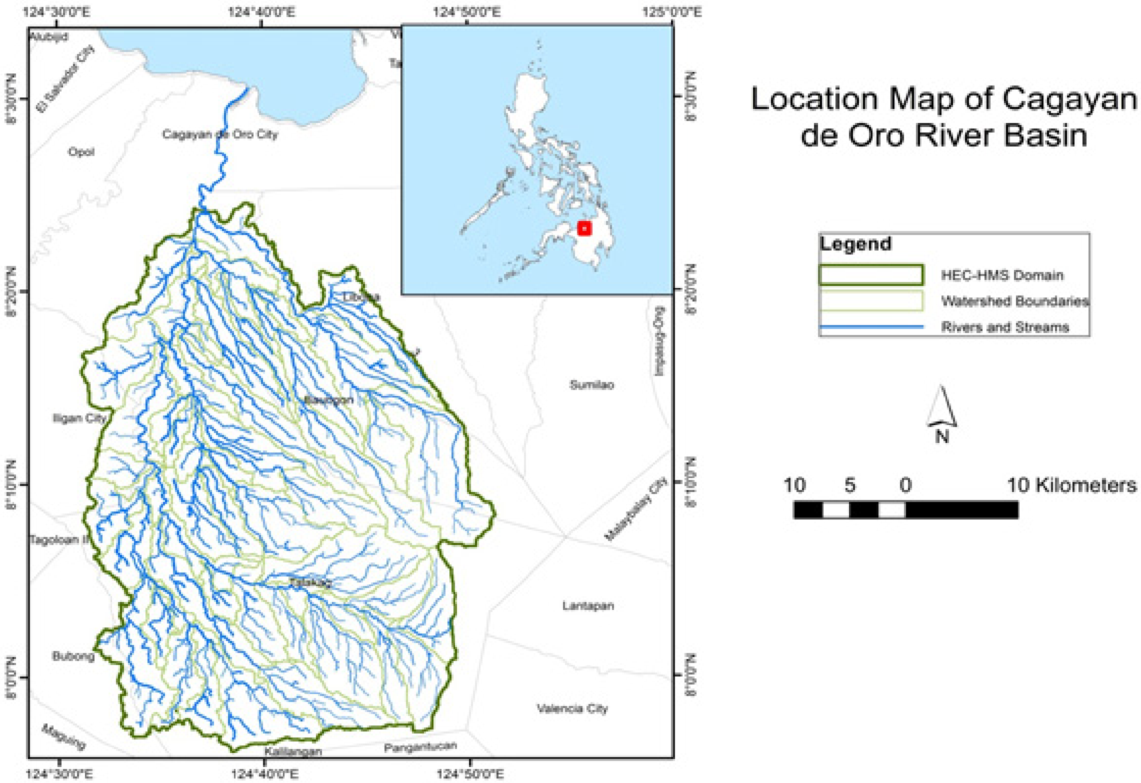

Figure 2. Cagayan de Oro River Basin Location Map

It includes Cagayan de Oro City in Misamis Oriental and the municipalities of Talakag, Baungon and Libona in Bukidnon. It has Cagayan de Oro River as its main channel with major tributaries including Kalawaig River, Tagite River, Bubunaoan River, and Tumalaong River and discharges the load to Macajalar Bay.

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 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 Management, and National Mapping and Resource Information Authority (NAMRIA). The soil and land cover of the Cagayan de Oro River Basin are shown in Figures 3 and 4, respectively.

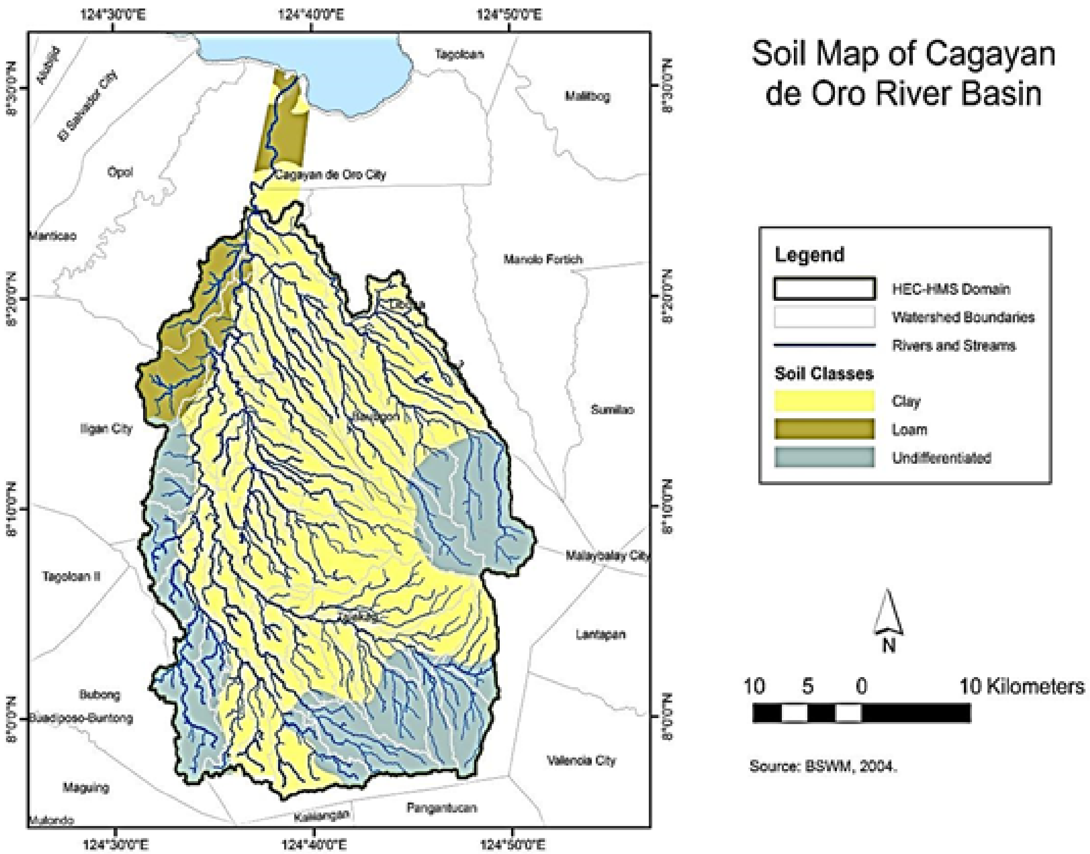

Figure 3. Cagayan de Oro River Basin Soil Map

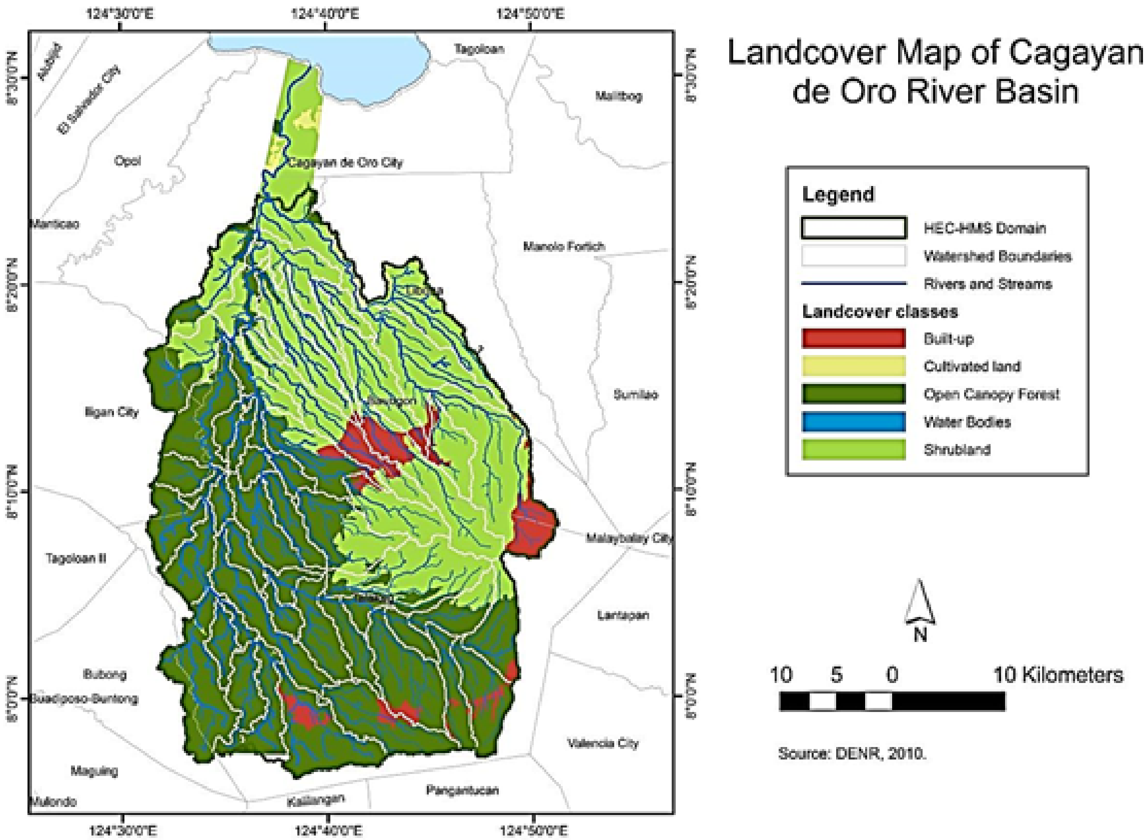

Figure 4. Cagayan de Oro River Basin Land Cover Map

DVC Methodology

DVC Methodology

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

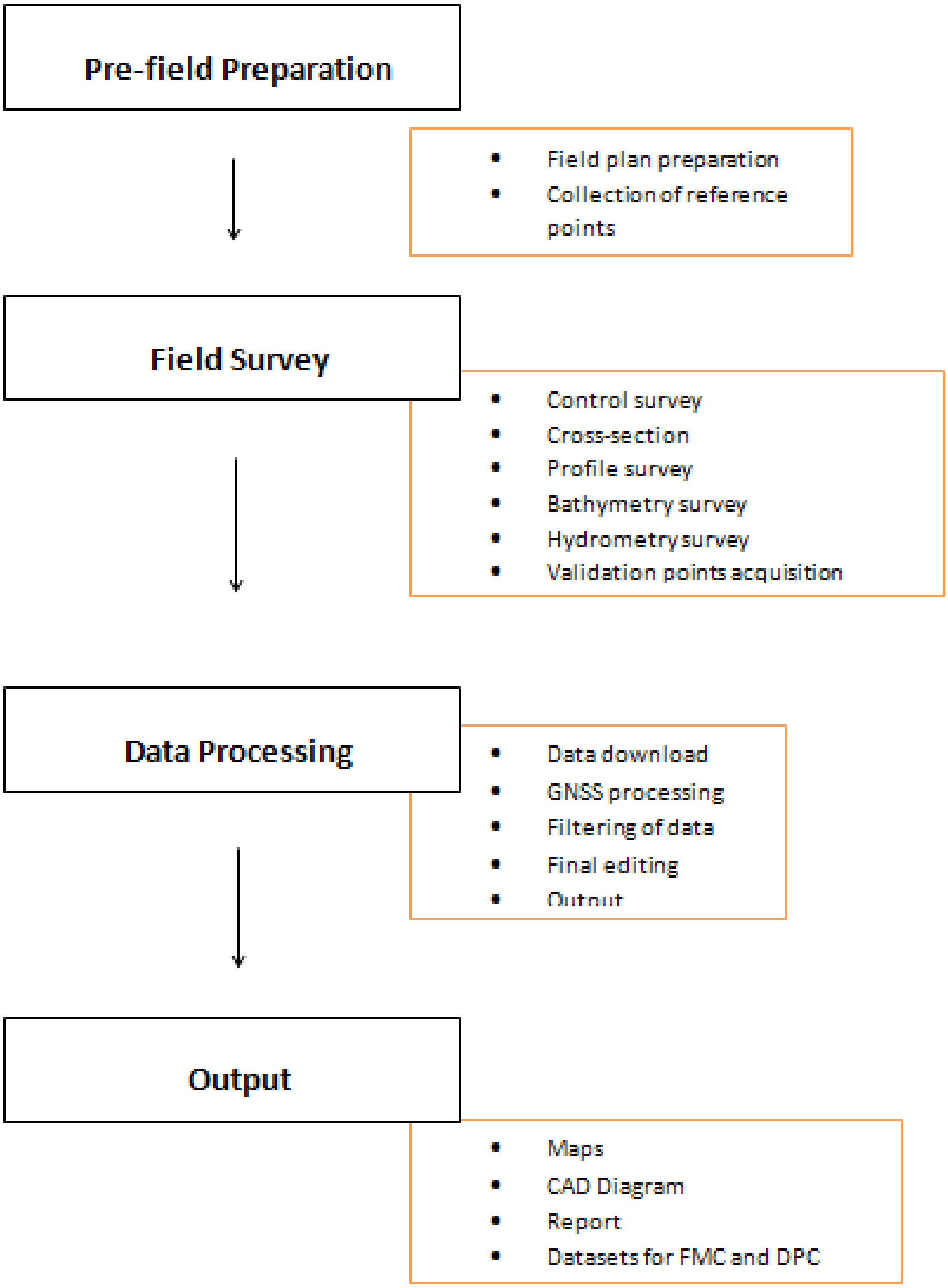

Figure 5. DVC Main Activities

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

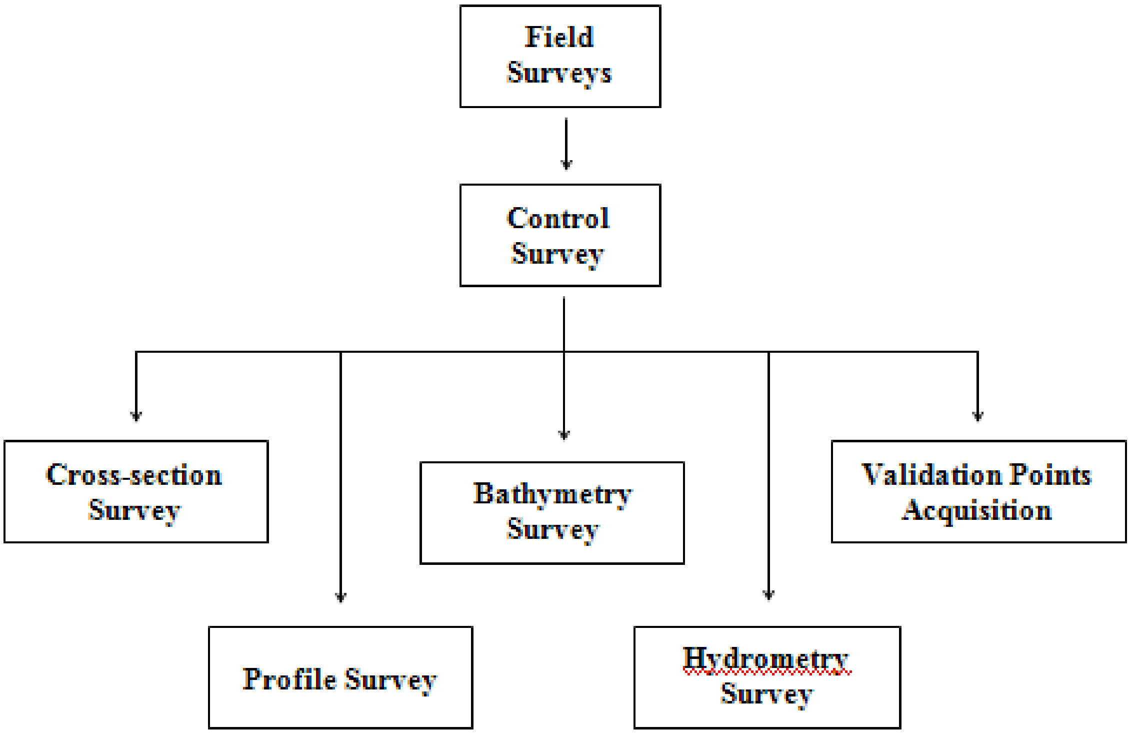

Figure 6. DVC Field Activities

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 centimeter 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 waterless 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 behavior 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) or by 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.

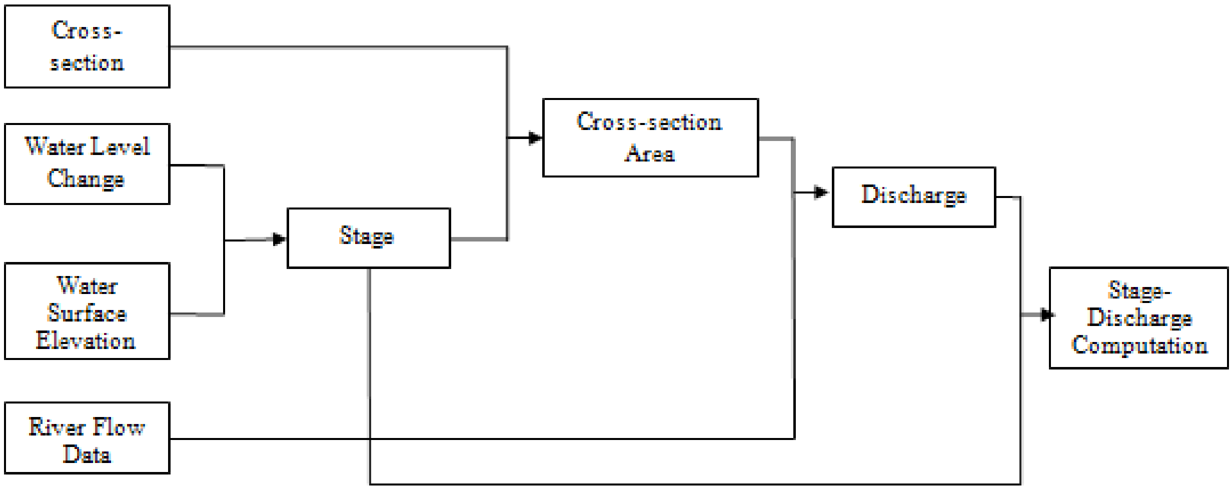

Figure 7. Flow Chart for Stage-Discharge Correlation Computation

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.

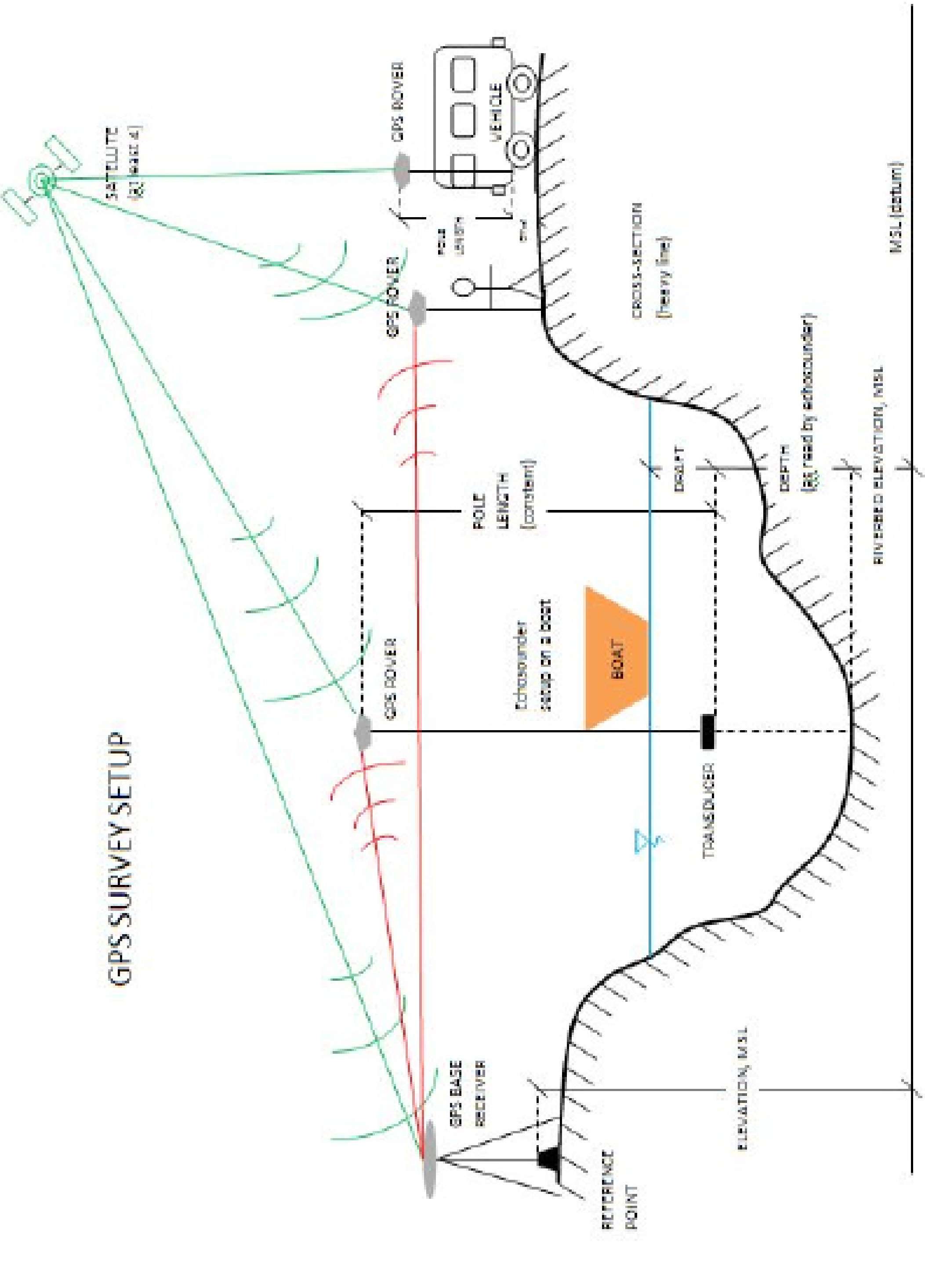

Figure 8. Set-up for GNSS Survey

3.3 Data Processing

Data processing procedures used by DVC are summarized in Figure 9.

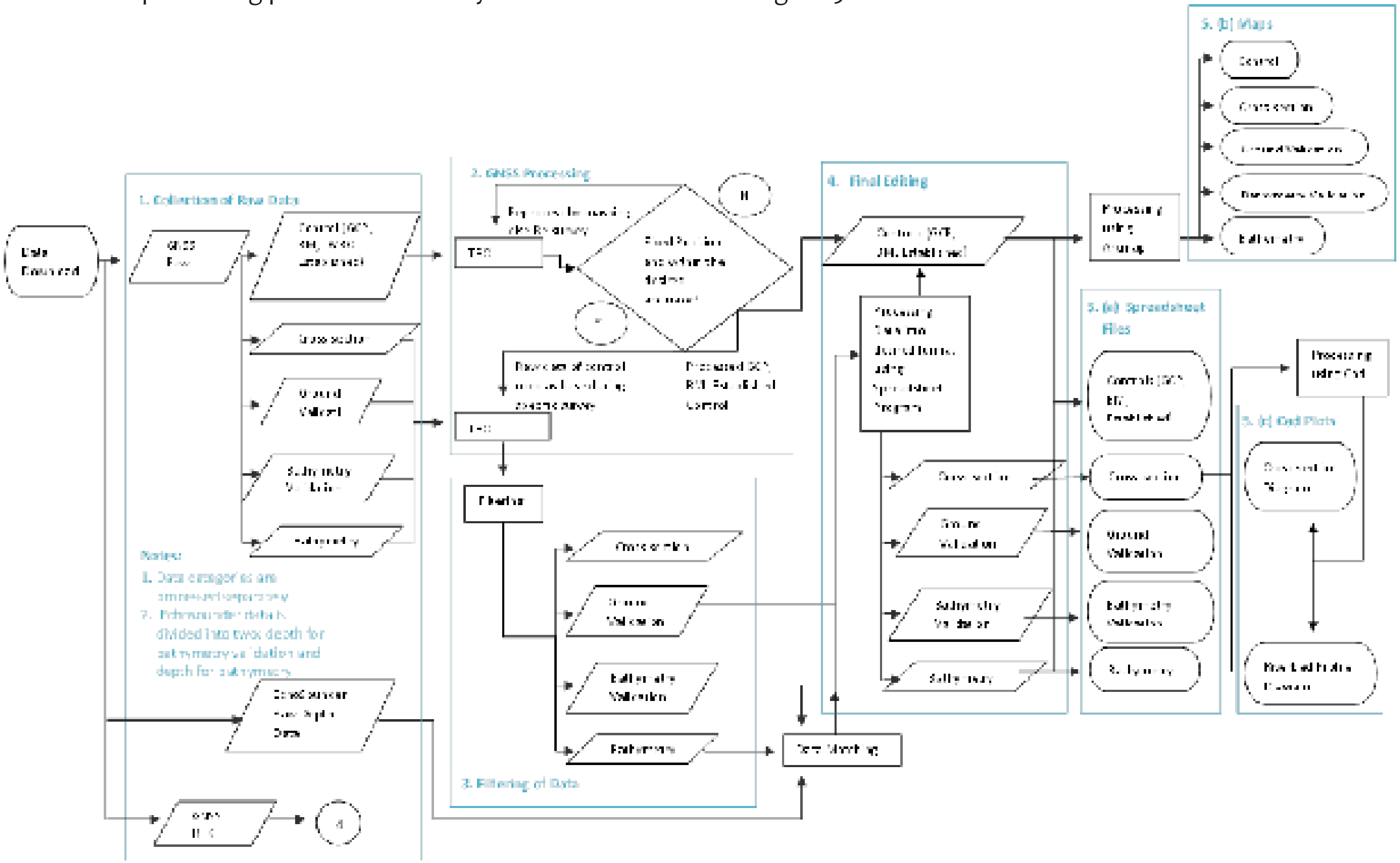

Figure 9. DVC Data Processing Methodology

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

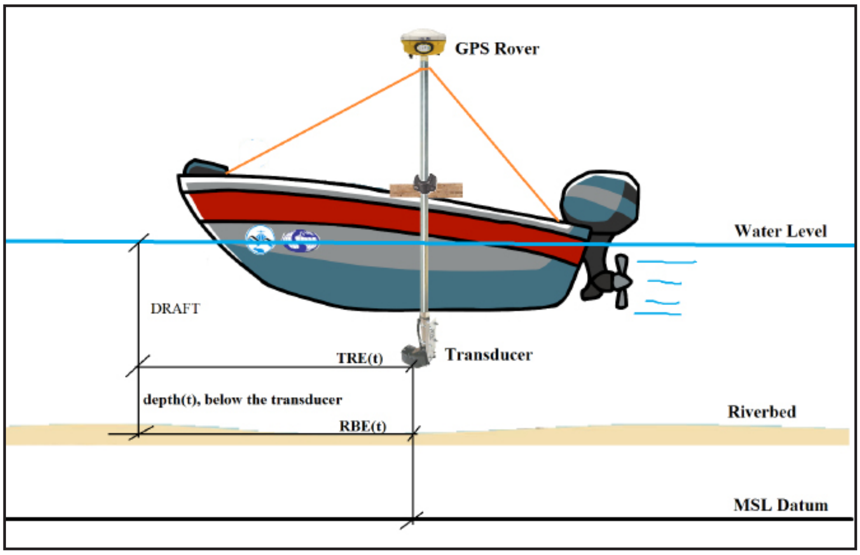

Figure 10. Illustration of Echo Sounder and GPS rover set-up for Bathymetric survey

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.

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.

Cagayan de Oro River Basin Survey

Cagayan de Oro River Basin Survey

The survey for Cagayan de Oro River Basin was conducted on February 1 – 10, 2012 with the following activities: control, cross-section and profile lines, bathymetric and hydrometric surveys.

Cagayan de Oro River consists of 12 delineated cross section lines with a total length of 25.6 km for both left and right banks starting from Brgy. Macasanding in the upstream down to Brgy. Macabalan and Brgy. Bonbon near the mouth of the river. The total length of profile lines is about 34 km for its both left and right banks.

4.1 Control Survey

Control survey was done on February 1, 2012. Three (3) NAMRIA established control points were considered for the static GNSS observations of Cagayan de Oro River System. These include a benchmark, TGBM, which is located in Brgy. Macabalan, Cagayan De Oro City; a third-order reference point, MSE-3241, situated at the center island along Macapagal Rd, Brgy. 10 (Poblacion), Cagayan de Oro City; and another third-order reference point, MSE-49, located in Brgy. Lumbia, Cagayan de Oro City. The location for the three (3) base stations is illustrated in Figure 11.

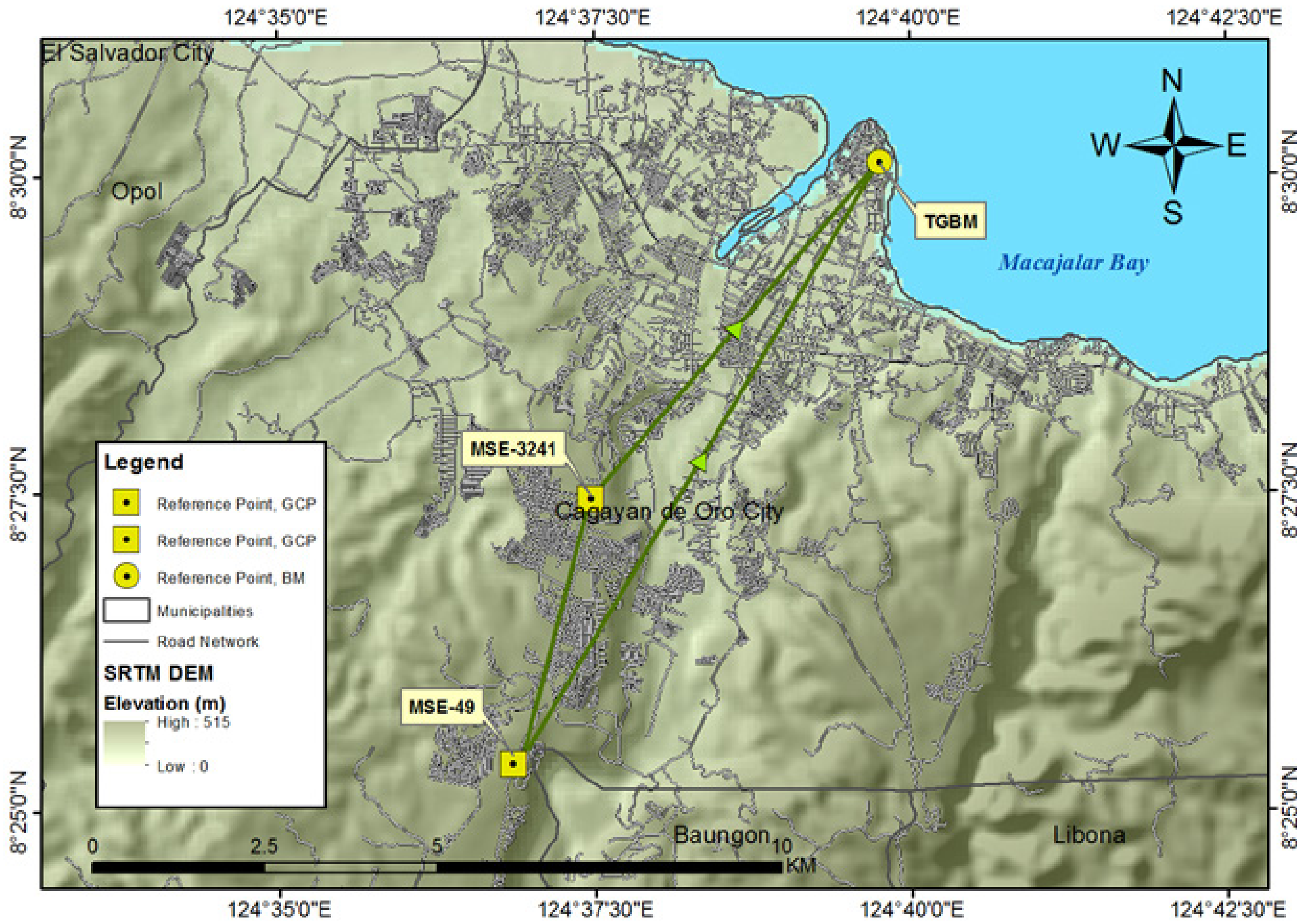

Figure 11. Location of control points

Cagayan de Oro River Basin Survey

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.

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

STATION NAME	ORDER OF ACCURACY	Geographic Coordinates WGS 84 Datum			Elevation (EGM08)	Elevation (above MSL)
		Latitude	Longitude	Ellipsoidal height		
Tidal Gauge Bench Mark (TGBM 2007)						4.016 m
Tidal Gauge Bench Mark (TGBM 2011)	1st	8030’5.75361” N	124039’46.04391” E	70.961 m.	1.145 m.	2.285 m.
MSE 3241	3rd	8027’27.49608” N	124037’28.59587” E	177.055 m.	106.968 m.	108.108 m.
MSE 49	3rd	8025’22.10941” N	124036’51.27533” E	250.522 m.	180.177 m.	181.317 m.

The recovered benchmark (TGBM) at NAMRIA Cagayan de Oro Primary Tide Station, Macabalan Port served as the vertical control point. Originally, the TGBM has no horizontal coordinates. By direct occupation of GPS receiver, the TGBM acquired the horizontal data. Likewise, the vertical data of GPS control points is in ellipsoidal height which was converted to mean sea level by applying the geoid model EGM08.

ERRATUM - SUPPLEMENT TO THE TGBM (ELEVATION above MSL)

A correction was made for the TGBM based from the NAMRIA Certification. It was reported on May 9, 2013 that the TGBM was re-established to a new location and was renamed as TGBM (2011). Thus, it was verified that the elevation 4.016 m (above zero tide staff) must be 2.2853 m (above mean sea level).

In this survey (Profile, Cross-section, Bathymetric Surveys and Flow Measurements in Cagayan de Oro River, Cagayan de Oro City), elevation used for computing the gathered data were based on the TGBM (2011). Therefore, all gathered data will be corrected.

The GNSS setup for the control points are shown in Figures 12 and 13:

Figure 12. Static GNSS observation on TGBM inside Macabalan Port

Figure 13. Static GNSS observation on MSE-49 in Brgy. Lumbia, Cagayan de Oro City

4.2 Cross-section Survey

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 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 by the team through differential post processed kinematic GNSS surveying on February 3 – 7, 2012.

A set of four (4) survey grade, dual frequency GPS receivers (Topcon Hiper Ga) were used. One receiver was set up on MSE 3241 as the base station with logging rate of one (1) second interval throughout the day for each day of cross section surveys. One receiver was used as rover for data acquisition of cross section lines on the left bank while a pair of GPS receivers, Trimble® SPS852 and SPS882 for base and rover.

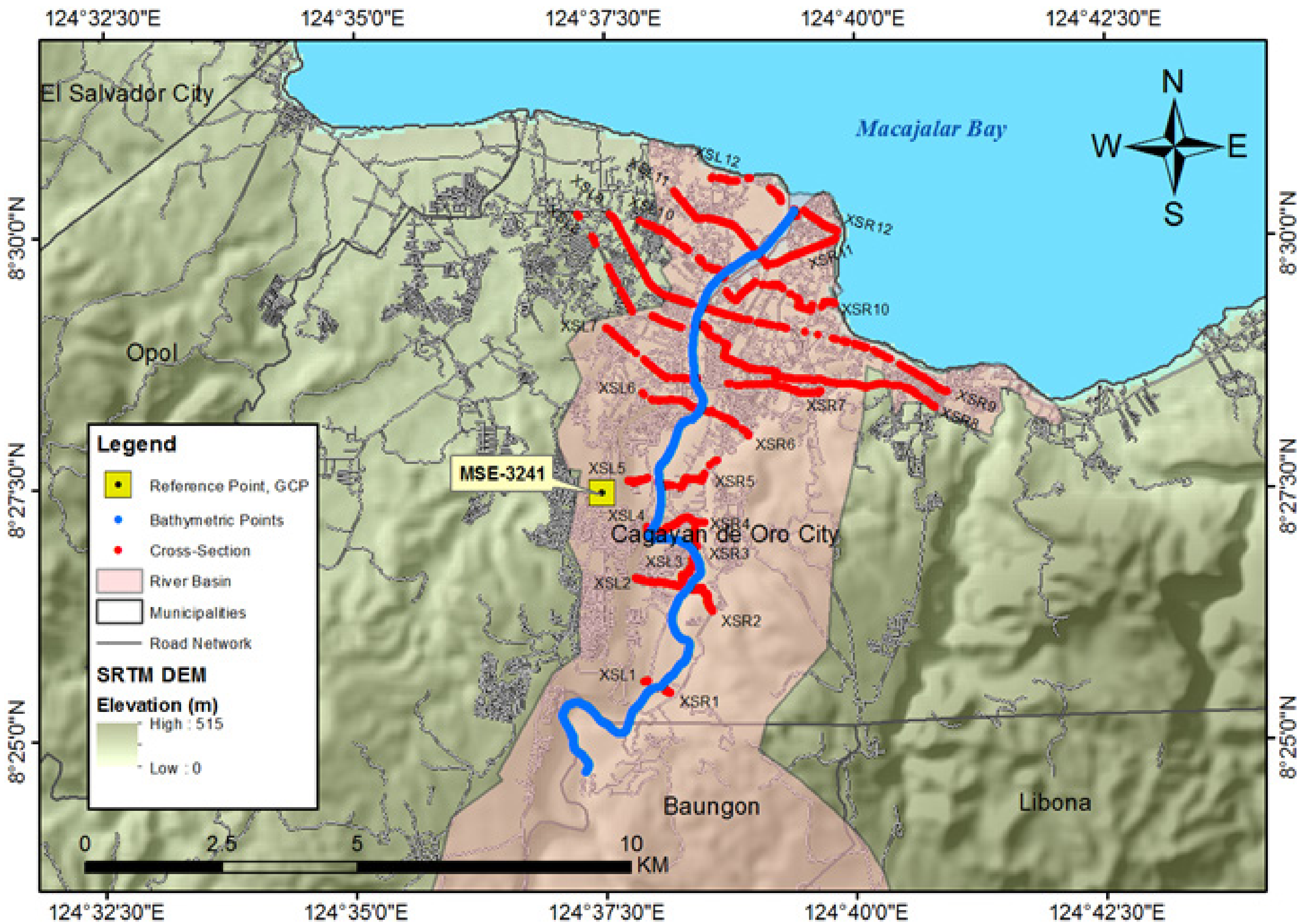

Figure 14. Cross-Section Survey for Cagayan de Oro River

The cross-sections are plotted from the left bank facing downstream. The variation in the elevation from the riverbed to the floodplain in Cagayan de Oro River is shown in Figures 15-26.

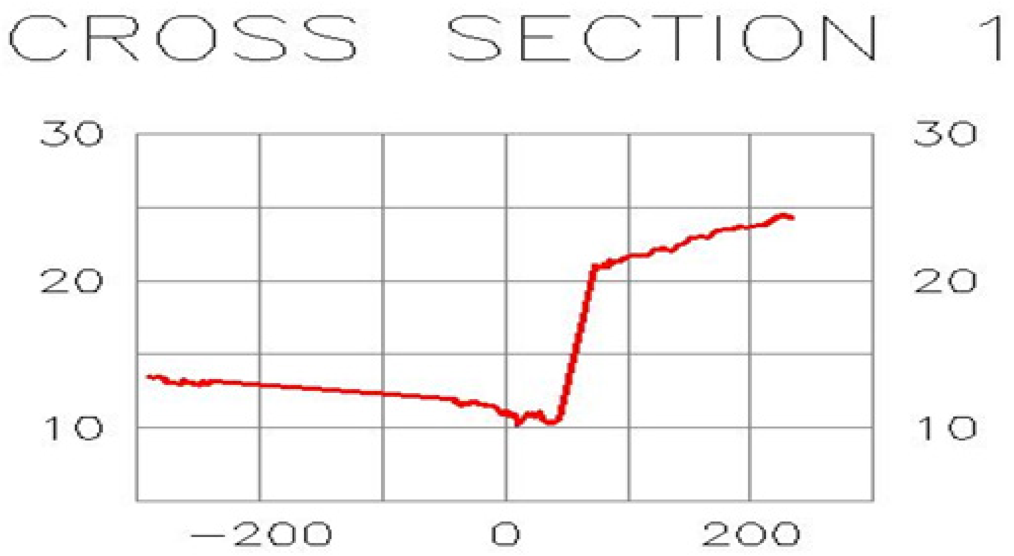

Figure 15. Cross-section 1 along CDO River

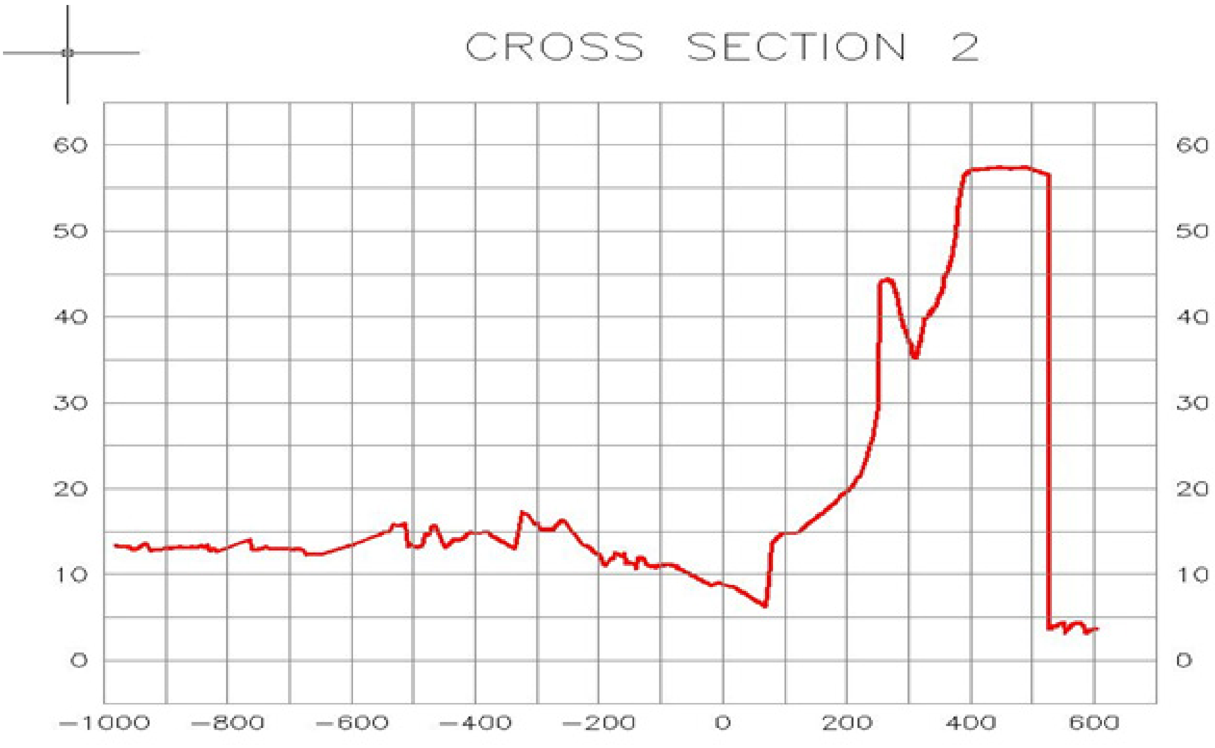

Figure 16. Cross-section 2 along CDO River

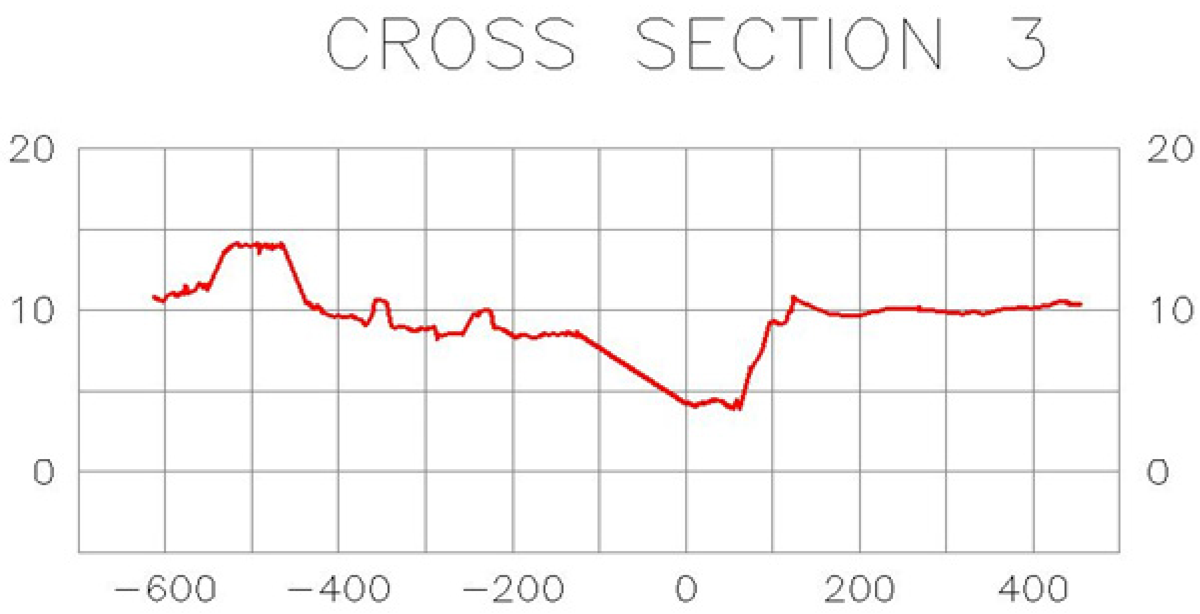

Figure 17. Cross-section 3 along CDO River

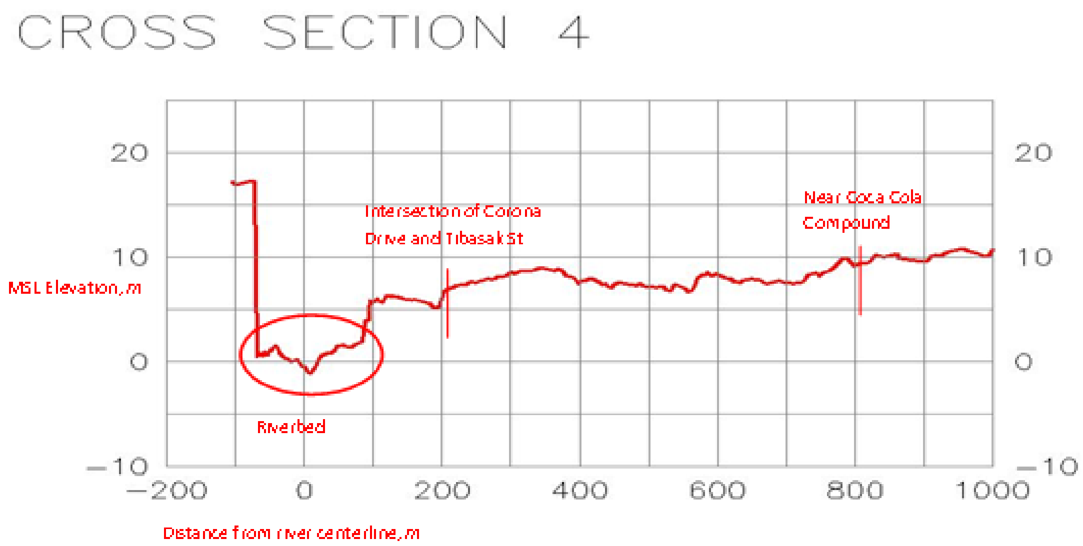

Figure 18. Cross-section 4 along CDO River

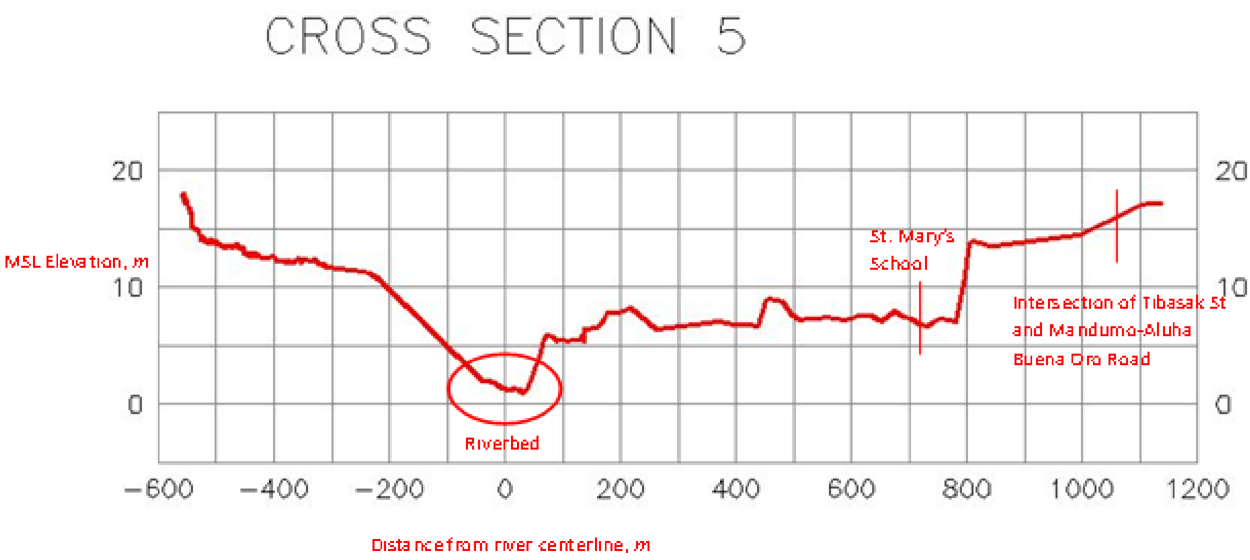

Figure 19. Cross-section 5 along CDO River

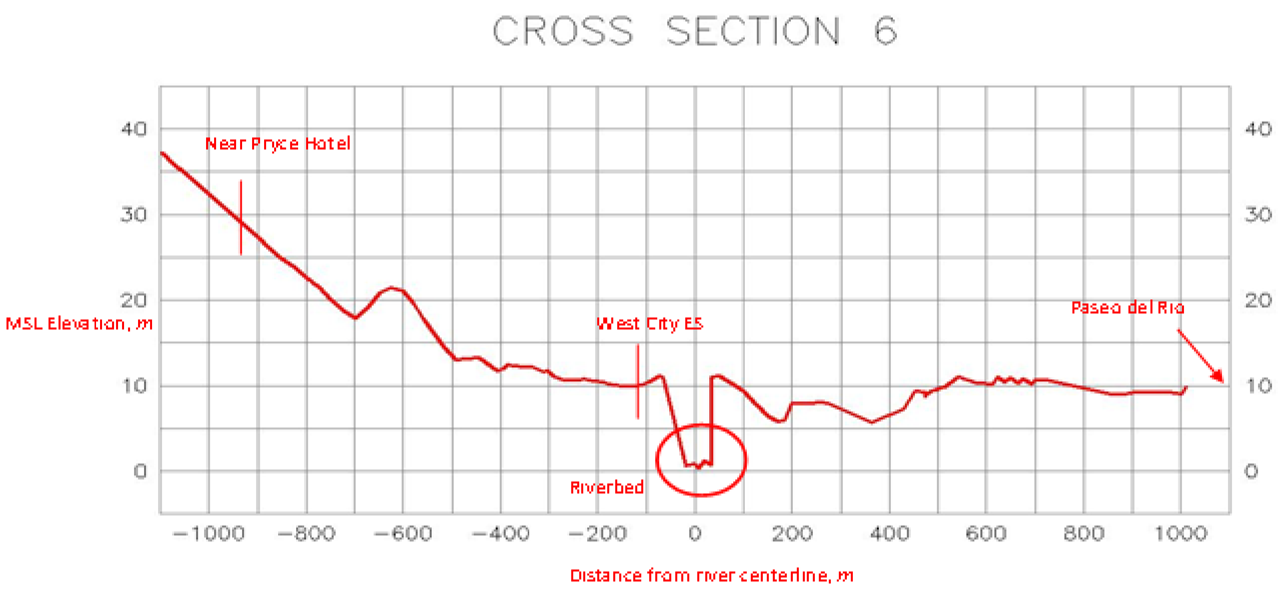

Figure 20. Cross-section 6 along CDO River

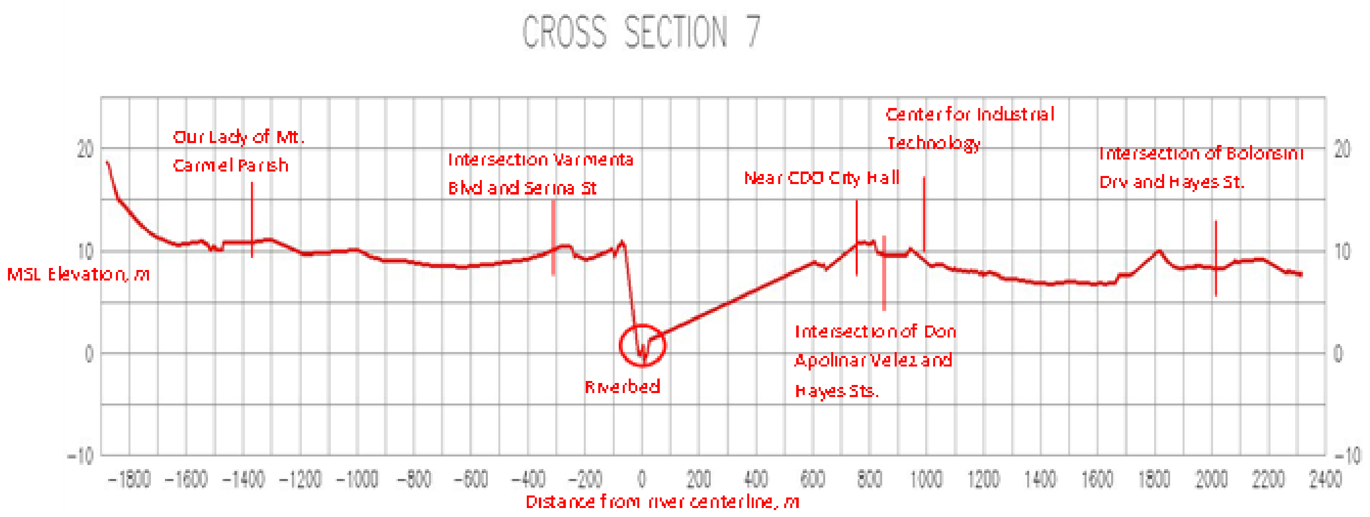

Figure 21. Cross-section 7 along CDO River

Figure 22. Cross-section 8 along CDO River

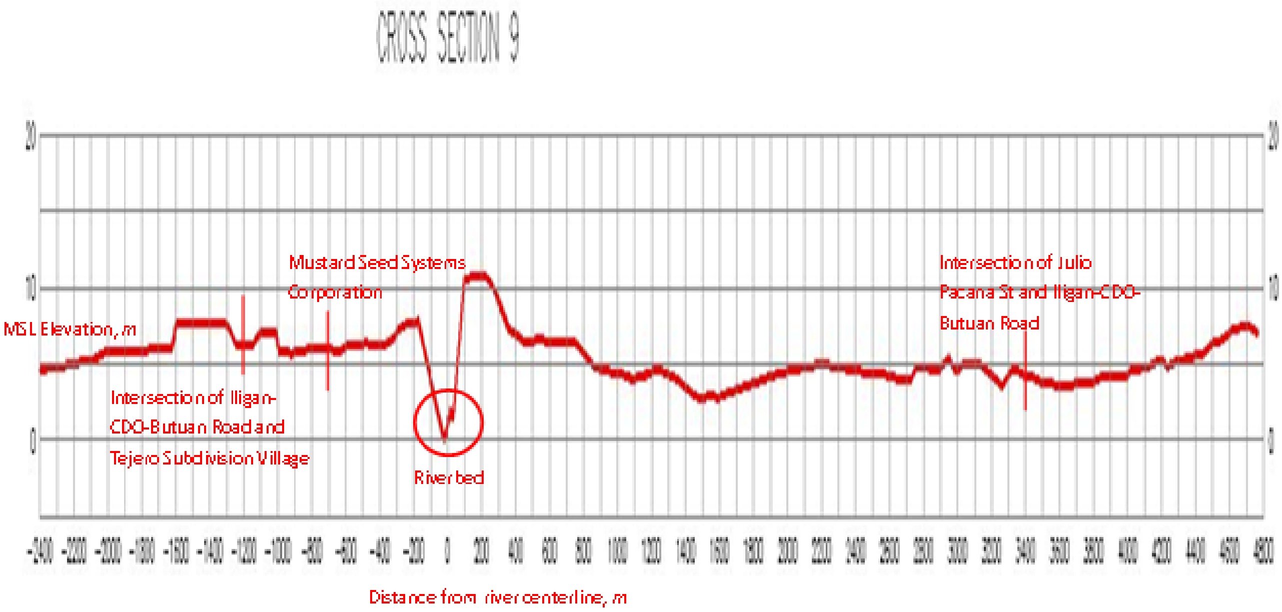

Figure 23. Cross-section 9 along CDO River

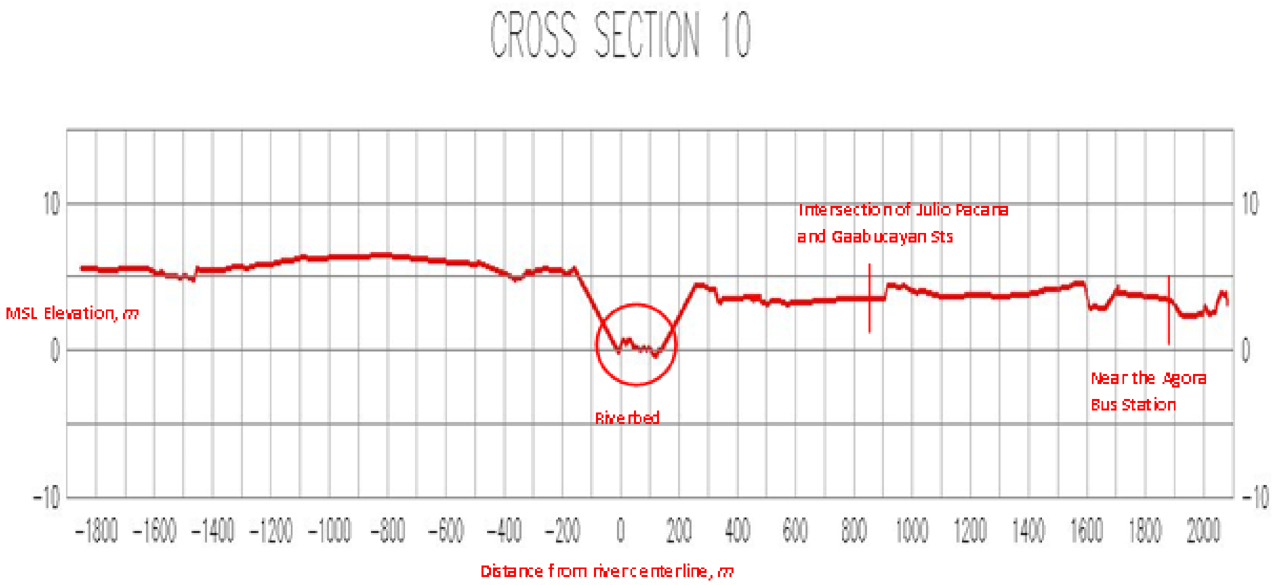

Figure 24. Cross-section 10 along CDO River

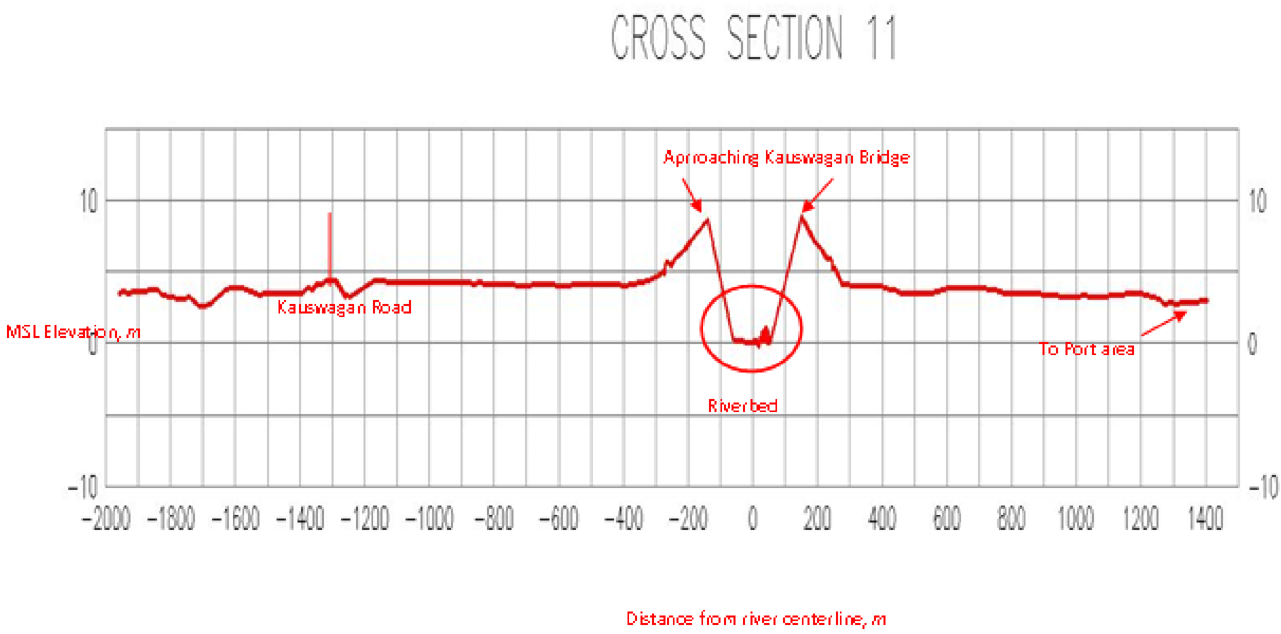

Figure 25. Cross-section 11 along CDO River

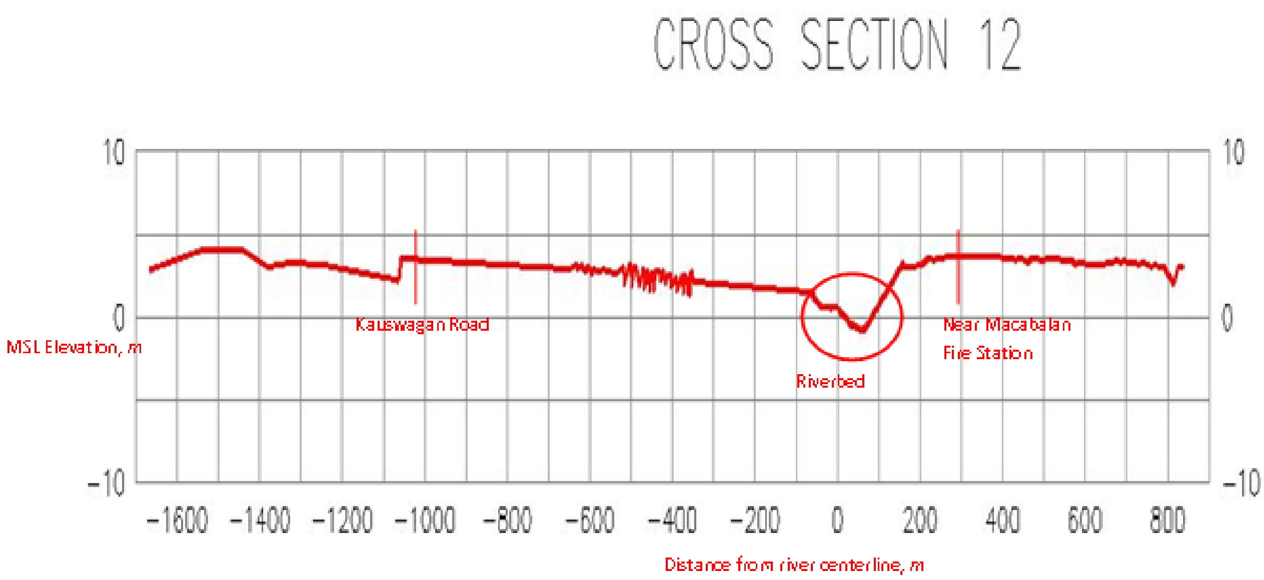

Figure 26. Cross-section 12 along CDO River

4.3 Profile Survey

The river profile survey was done simultaneously with cross-section survey on February 3 – 7, 2012. Profile of Cagayan de Oro River from upstream to downstream is plotted using CAD. The graph of the left profile is shown in Figure 27 while the right profile is in Figure 28.

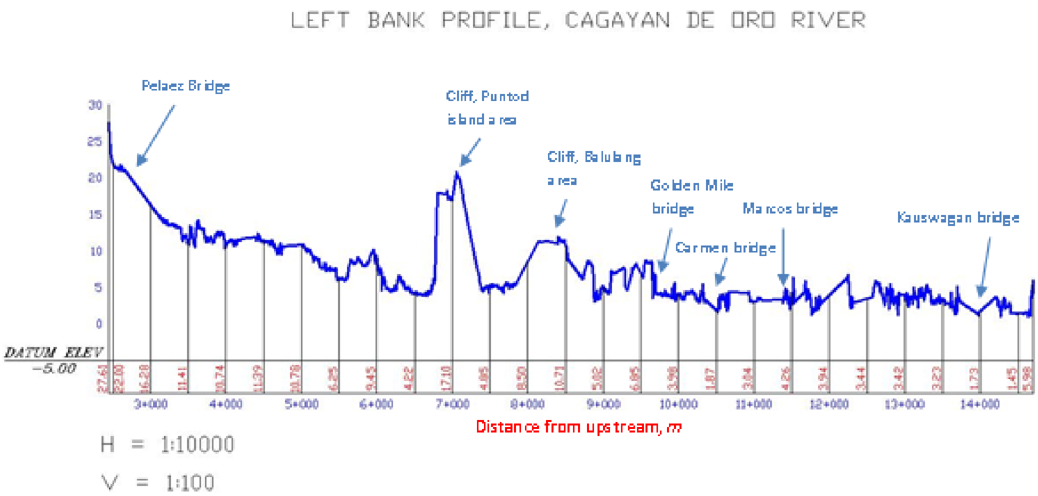

Figure 27. Left bank profile of CDO River

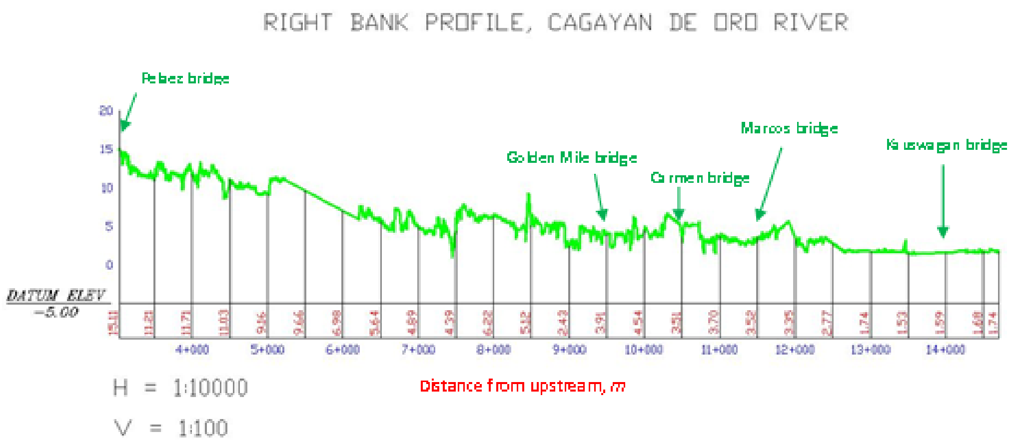

Figure 28. Right bank profile of CDO River

4.3 Bathymetric Survey

The bathymetry of the river channel was surveyed using differential GNSS surveying technique that obtains horizontal and vertical position with a Hi-Target™ single beam echo sounder that were utilized in measuring the depth of the river. The gathered data is centerline and zigzag sweep.

Bathymetric survey started in Brgy. Balulang down to Brgy. Bonbon on February 5, 2012 with the equipment installed on a pump boat. While on February 6, 2012 the equipment was installed in a rafting rubber boat that started from Cabula Bridge to Brgy. Balulang. Setup during the Cagayan de Oro bathymetry survey is illustrated in Figure 29 to 31.

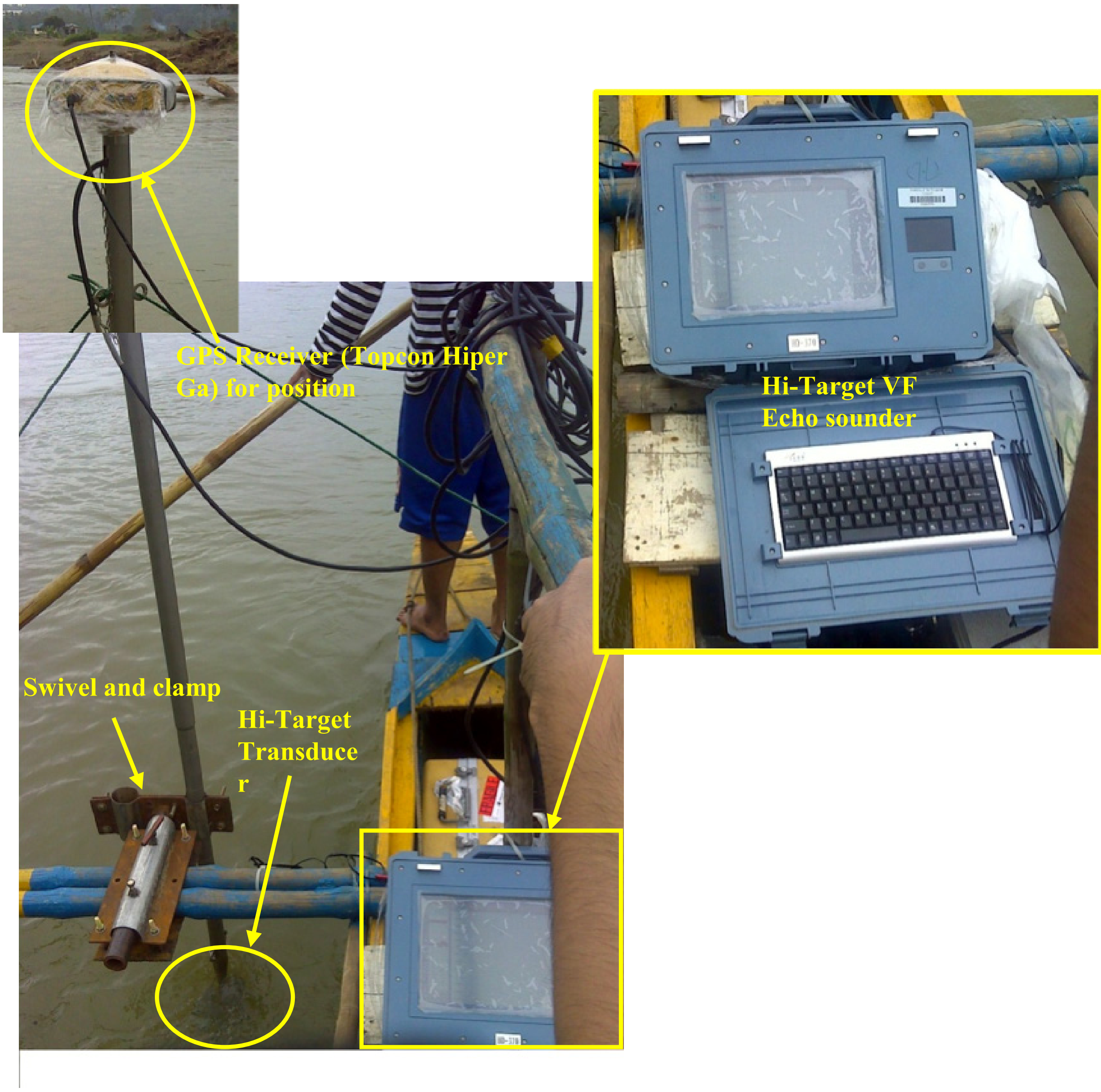

Figure 29. Bathymetric survey setup using Topcon® Hiper Ga mounted on top of the Hi-Target™ Transducer

Figure 30. Rafting rubber boat setup of bathymetric survey instrument

Figure 31. Other view of bathymetric equipment setup with Red Rafts Team

An approximate centerline length of 14.9 km and a zigzag sweep length of 35.7 km were covered starting from downstream in Brgy. Bonbon up to Brgy. Pualas, Cagayan de Oro City. Data gathered during the bathymetry survey is illustrated in Figure 32.

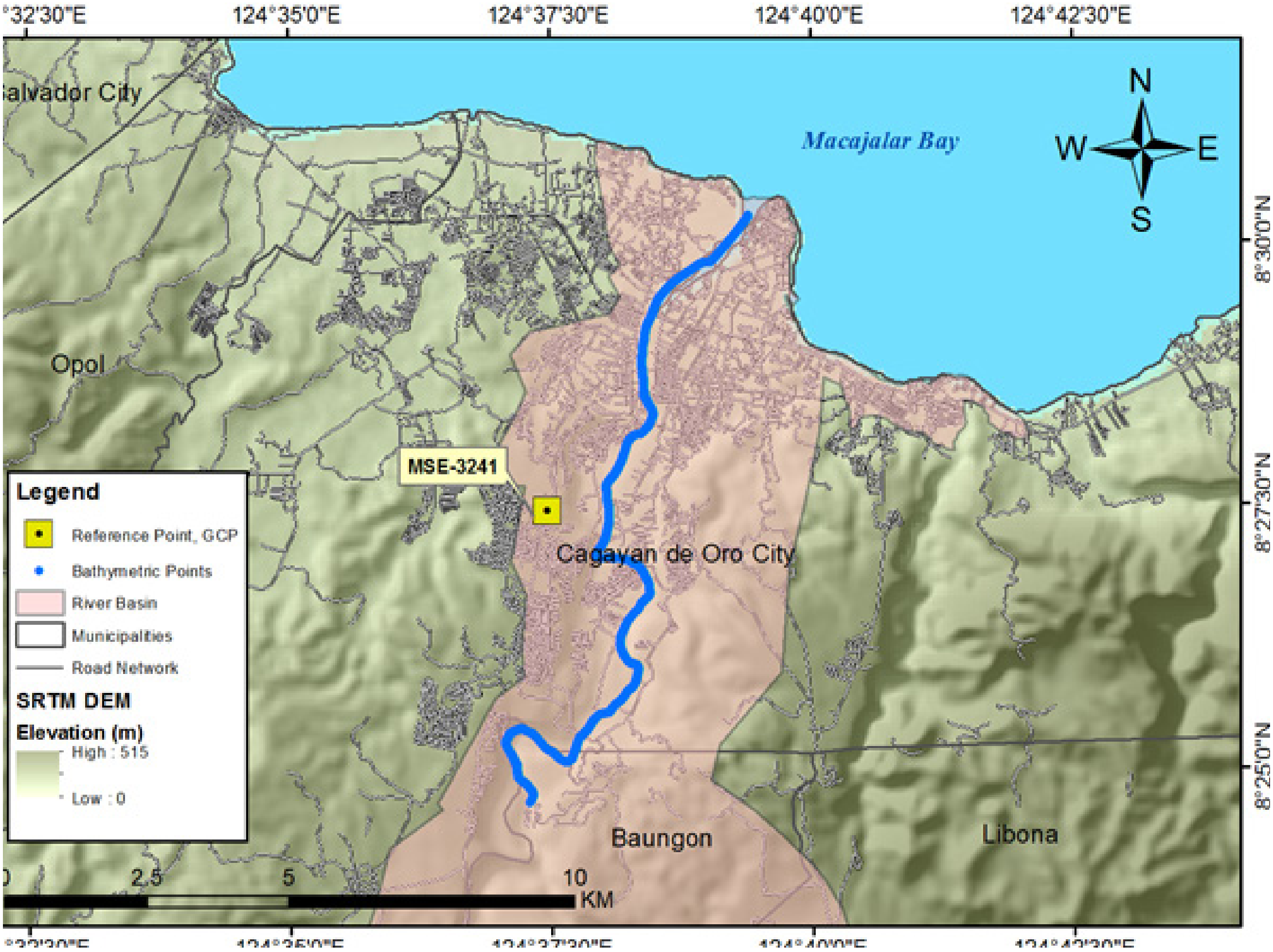

Figure 32. Bathymetry Survey along Cagayan de Oro River

4.4 Hydrometric Survey

Different sensors were deployed on the banks of Cagayan de Oro 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.

First deployment was made in Cabula Bridge using a velocity meter and a depth gauge on February 2, 2012.

On February 4, 2012, the sensors were retrieved from Cabula Bridge and were deployed along Pelaez Bridge which is the outlet of the Cagayan de Oro watershed. Cross section was then obtained after the deployment of sensors. Location of deployment site is illustrated in Figure 33 and the set-up of the sensors are shown in Figure 34.

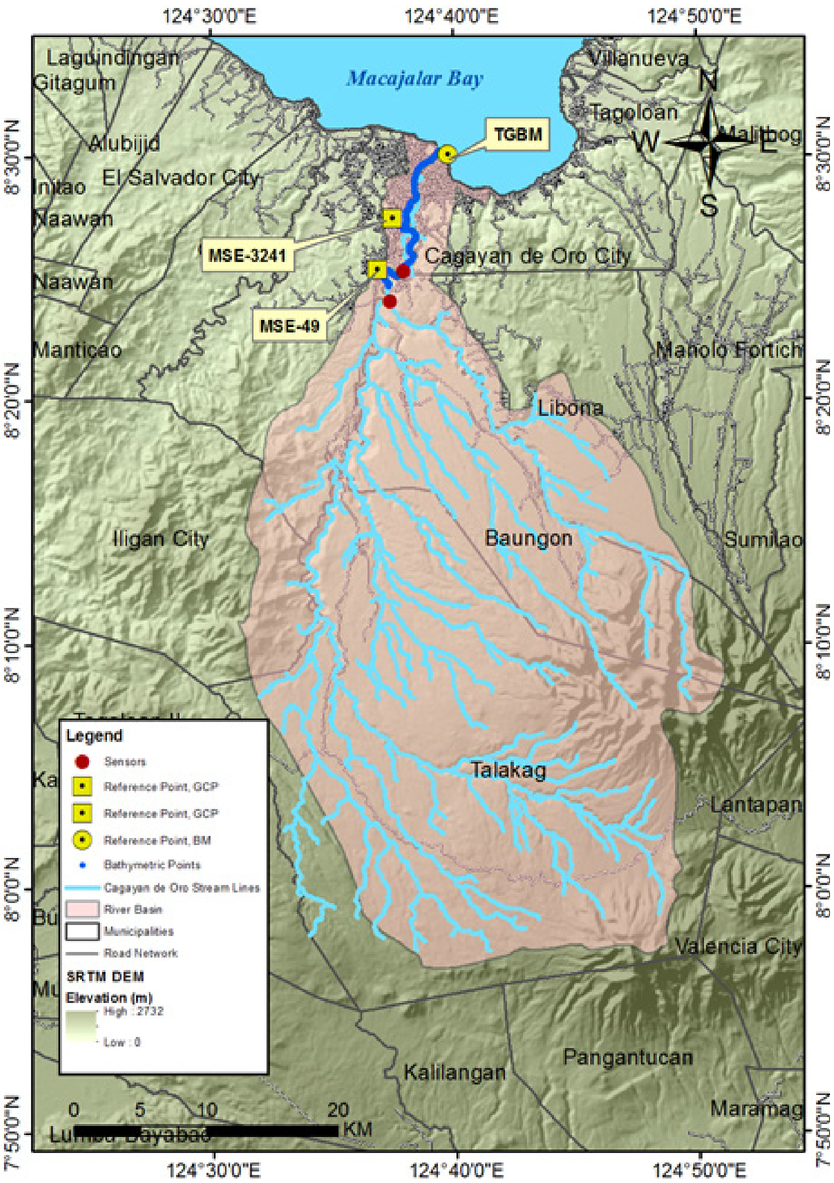

Figure 33. Depth Gauge and Velocity Meter Deployment Site

Figure 34. Sensors setup of velocity meter and depth gauge

The data gathered from the depth gauge shows the behavior of the water level within the observation period from February 2 to 4, 2012 in Cabula Bridge, Brgy. Lumbia, Cagayan de Oro City and from February 5 to 10 in Pelaez Bridge, Brgy. Macasandig, Cagayan de Oro City.

Cross-Sectional data at Cabula Bridge, Brgy. Lumbia is shown in Figure 35.

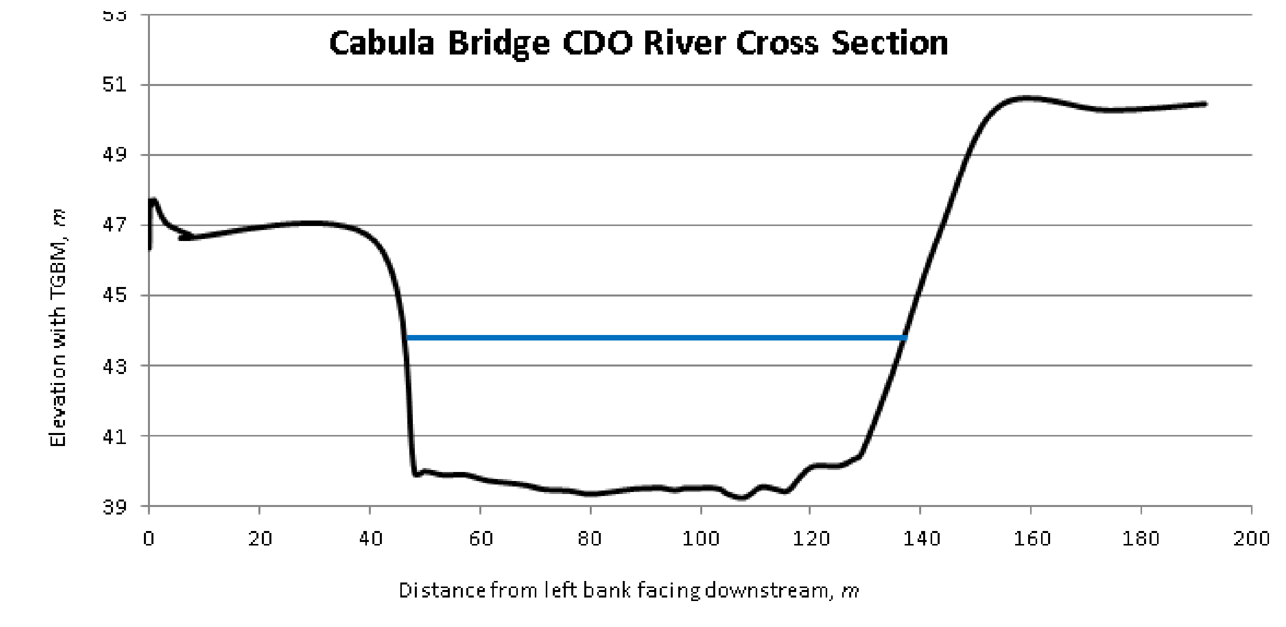

Figure 35. Relationship between the stage and the cross section at Cabula Bridge

Stage data from the deployed depth gauge from February 2 – 4, 2012 is shown in Figure 36.

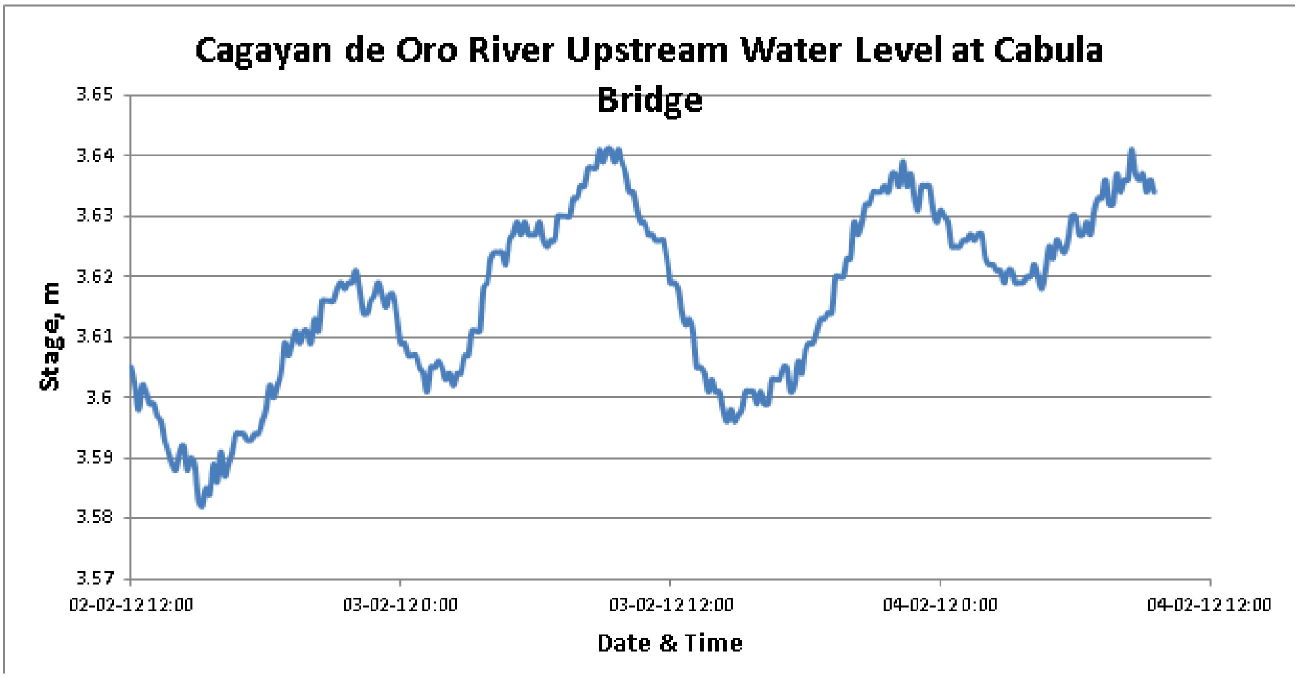

Figure 36. Stage data in Cabula Bridge, Brgy. Lumbia Cagayan de Oro City

Water velocity data from the deployed velocity meter from February 2-4, 2012 is shown in Figure 37.

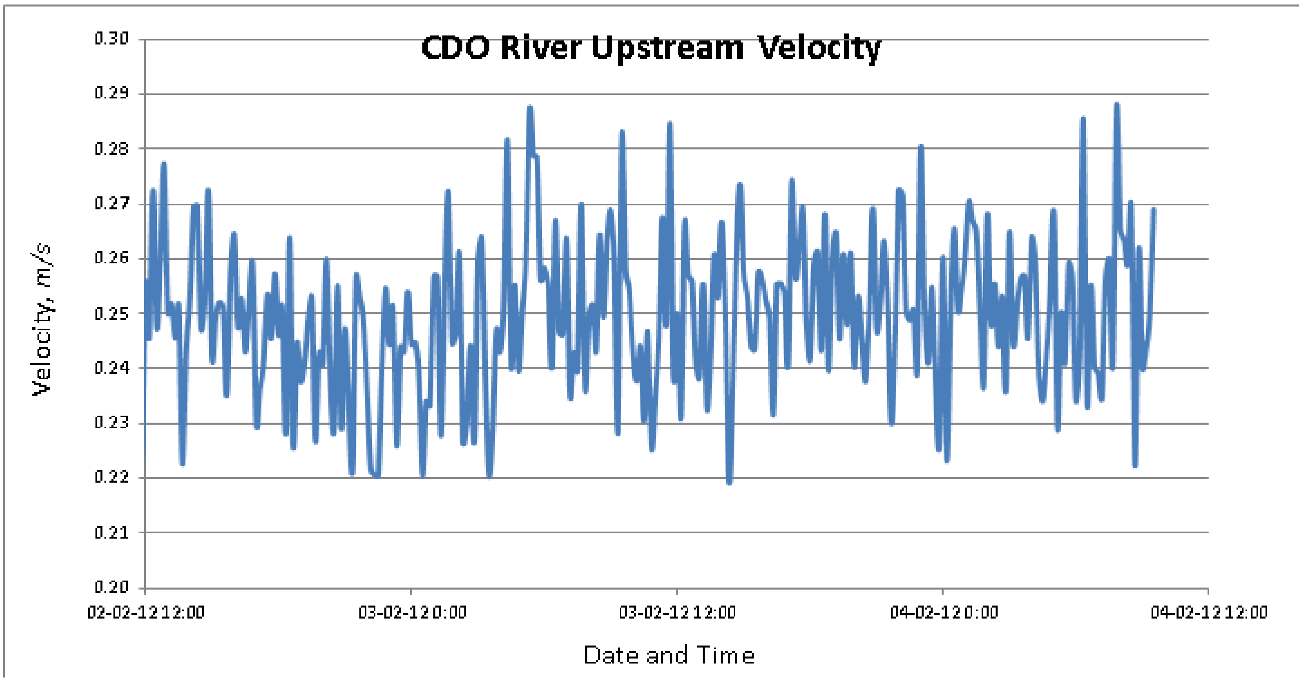

Figure 37. Velocity Plot at Cabula Bridge, Brgy. Lumbia Cagayan de Oro City

The relationship between the stage or water surface elevation referred to MSL and river discharge on a specific area of the river resulted to an $R^2 = 0.9754$ is illustrated in Figure 38. A value approaching $R^2 = 1$ indicates a good correlation.

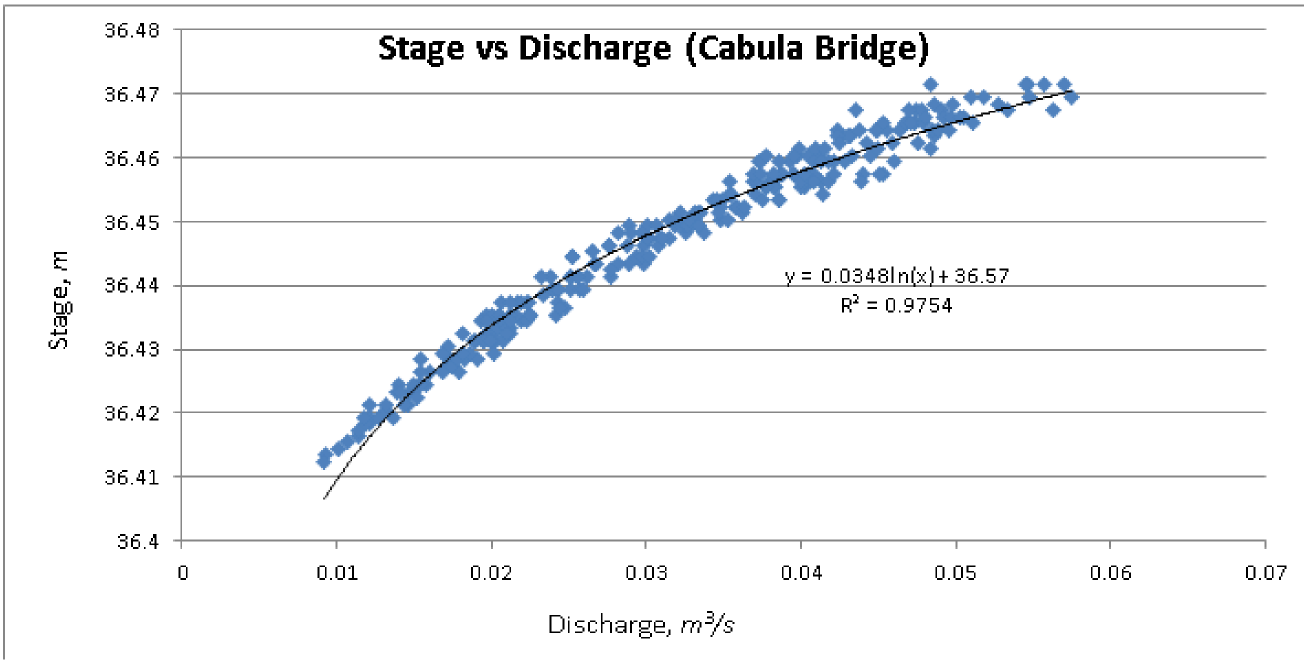

Figure 38. Stage-discharge computation in Cabula Bridge, Brgy. Lumbia Cagayan de Oro City

Cross-Sectional data at Pelaez Bridge, Brgy. Macasandig, Cagayan de Oro City is shown in Figure 39.

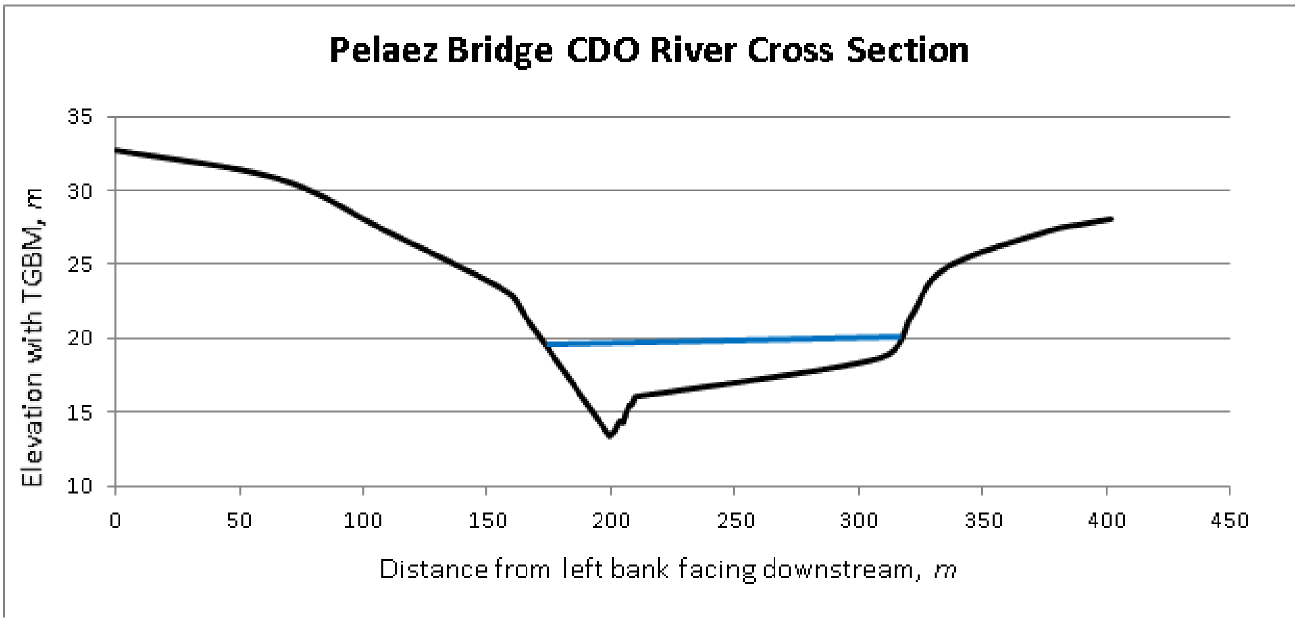

Figure 39. Relationship between the stage and the cross section at Pelaez Bridge, Brgy. Macasandig, Cagayan de Oro City

Stage data from the deployed depth gauge at Pelaez Bridge from February 5 – 10, 2012 is shown in Figure 40.

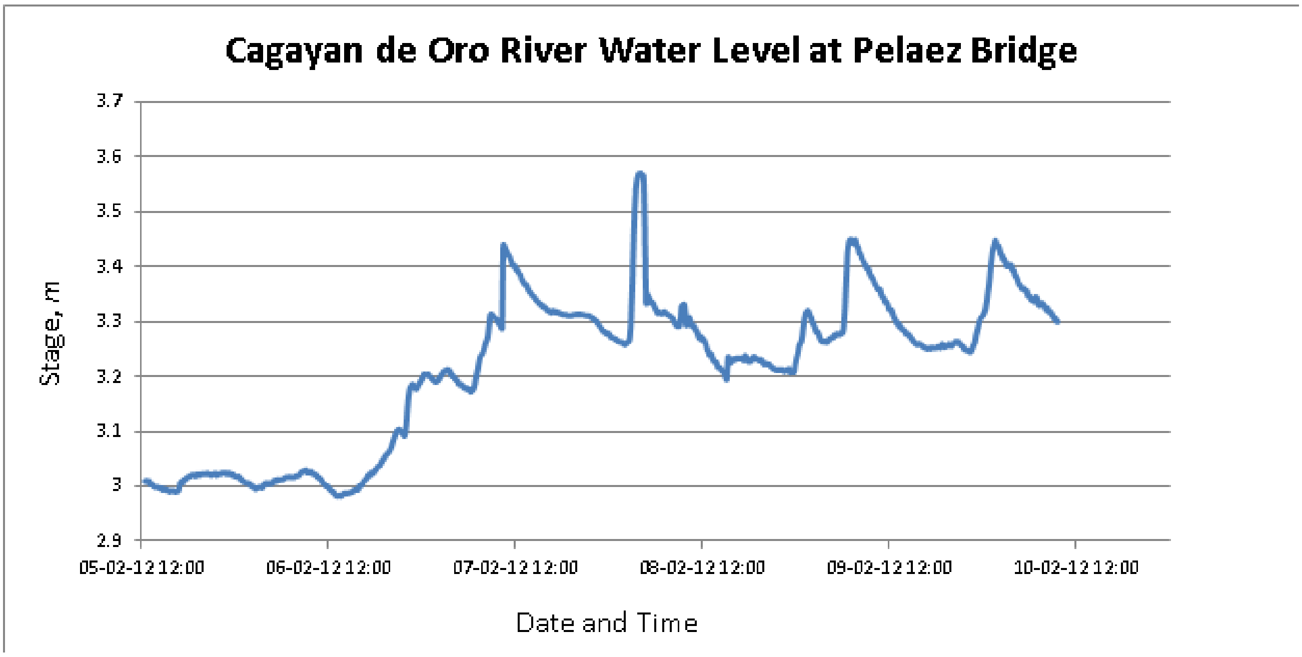

Figure 40. Stage Plot at Pelaez Bridge, Brgy. Macasandig, Cagayan de Oro City

Water velocity data from the deployed velocity meter at Pelaez Bridge from February 5-10, 2012 is shown in Figure 41.

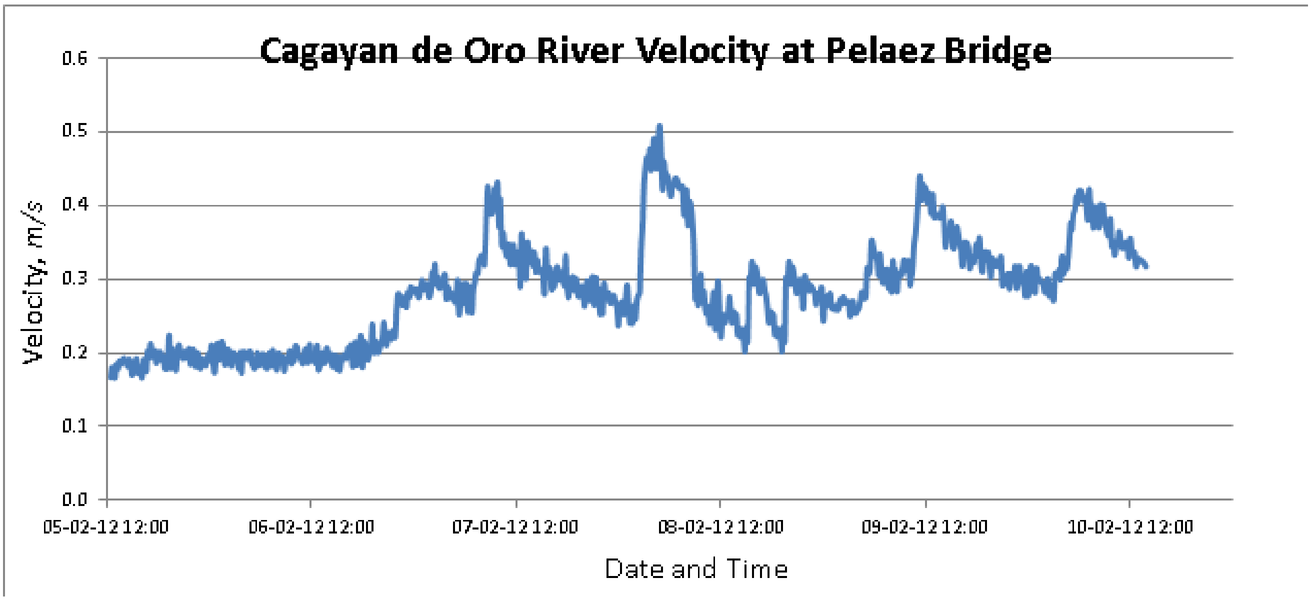

Figure 41. Velocity Plot at Pelaez Bridge, Brgy. Macasandig, Cagayan de Oro City

The relationship between the stage or water surface elevation referred to MSL and river discharge on a specific area of the river resulted to an R2 = 0.9754 is illustrated in Figure 42. A value approaching R2 = 1 indicates a good correlation.

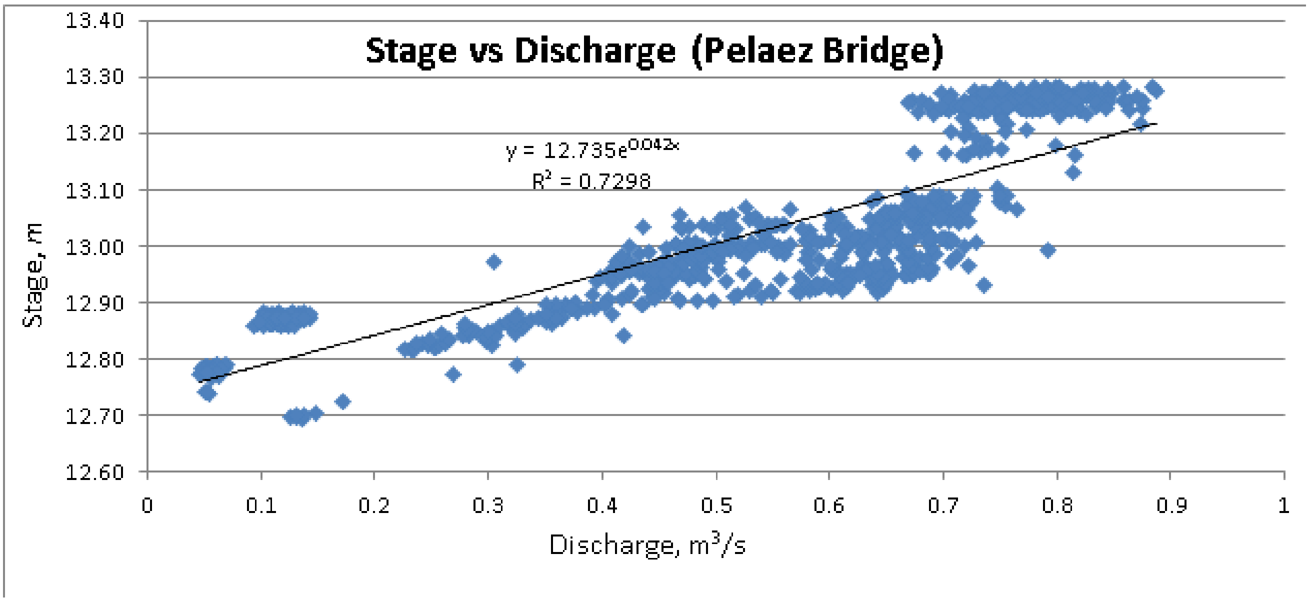

Figure 42. Stage-discharge computation at Pelaez Bridge, Brgy. Macasandig, Cagayan de Oro City

Annexes

Annexes

ANNEX A. 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 Echo sounder	Hi-Target	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
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 B. THE SURVEY TEAM

Designation	Name	Agency/Affiliation
Supervising the survey activities	ENRICO C. PARINGIT, D.Eng.	UP TCAGP
Survey Team Coordinator	ENGR. JOEMARIE S. CABALLERO	UP TCAGP
Bathymetric Survey Team	ENGR. GLADYS MAE APAT	UP TCAGP
	ENGR. DEXTER T. LOZANO	UP TCAGP
Profile Survey Team	ENGR. BERNARD PAUL D. MARAMOT	UP TCAGP
	GERARD M. FRANCISCO	UP TCAGP
Cross Section Survey Team	ENGR. KARLVIN DAVID CUARESMA	UP TCAGP
	JAMES P. NOVILLA	UP TCAGP

Annexes

ANNEX C. NAMRIA CERTIFICATION

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

April 17, 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: **MISAMIS ORIENTAL**
Station Name: **ME-TGBM**

Island: **Mindanao**	Municipality: **CAGAYAN DE ORO CITY**	Barangay: **MACABALAN**
Elevation: **2.2853 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

TGBM
It is located inside Macabalan Wharf, Port of Cagayan De Oro City. It is on the wharf floor, about 220 cm NE of the tide house and is about 45 cm NW of the concrete gutter.
Mark is the head of a 2" bronze rod set flush on a 10"x 10" cement putty with inscriptions "TGBM 2011 NAMRIA".

Requesting Party:	**Melchor Nery**
Pupose:	**Reference**
OR Number:	**3943536 B**
T.N.:	**2013-0306**

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

9 9 0 4 1 7 2 0 1 3 1 5 0 4 2 2

CIP/4/01/12/09/814

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 18, 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: **MISAMIS ORIENTAL**
Station Name: **MSE-3241**
Order: **3rd**

Island: **MINDANAO**
Municipality: **CAGAYAN DE ORO CITY (CAPITAL)**
Barangay: **BARANGAY 10 (POB.)**

PRS92 Coordinates

Latitude: **8° 27' 31.07607"** Longitude: **124° 37' 23.18891"** Ellipsoidal Hgt: **109.46700 m.**

WGS84 Coordinates

Latitude: **8° 27' 27.49608"** Longitude: **124° 37' 28.59587"** Ellipsoidal Hgt: **177.05500 m.**

PTM Coordinates

Northing: **935289.375 m.** Easting: **458499.251 m.** Zone: **5**

UTM Coordinates

Northing: **935,314.30** Easting: **678,684.71** Zone: **51**

Location Description

MSE-3241
Is located at the center island along Macapagal Rd., Brgy. 10 (Pob.), Cagayan de Oro City. It is situated between Sungole Bldg. and Super Mart Mall, about 20 m. facing the mall entrance. Mark is the head of a 4 in. copper nail embedded on a 25 cm. x 25 cm. concrete block, with inscriptions "MSE-3241 2007 NAMRIA".

Requesting Party: **UP DREAM/ Melchor Nery**
Pupose: **Reference**
OR Number: **3943540 B**
T.N.: **2013-0311**

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

9904182013101618

CERTIFICATION INTERNATIONAL ISO 9001:2008
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
Lawton Avenue, Fort Andres Bonifacio, 1634 Taguig City

9 May 2013

CERTIFICATION

TO WHOM IT MAY CONCERN:

This is to certify that according to our records, the description and elevations of tidal benchmarks TGBM (2007) and TGBM (2011) in Macabalan Port, Cagayan de Oro City are as follows:

TGBM (2007) – It is located inside Macabalan Port, Cagayan de Oro City. It is 45 cm from the SW corner of the tide house and situated on top of the tide house concrete pavement. Mark is the head of a 3/16"stainless steel bolt drilled on the concrete, on a 20 cm x 20 cm cement putty with inscription "TGMB 2007 NAMRIA".

Elevation: 4.016 meters above zero tide staff.

TGBM (2011) - It is located inside Macabalan Port, Cagayan de Oro City. It is set on the wharf floor, about 220 cm NE of the tide house and is about 45 cm NW of the concrete gutter. Mark is the head of a 2"bronze rod set flush on a 10" x 10"cement putty with inscriptions "TGBM 2011 NAMRIA".

Elevation: 2.2853 meters above mean sea level.
(Nov-2007-May 2011 series of observation)

4.7553 meters above zero tide staff.

This certification is issued upon the request of Engr. Joemarie S. Caballero of the University of the Philippines for whatever legal purpose it may serve.

Commodore ROMEO I. HO
Director, Hydrography Department

www.namria.gov.ph oss@namria.gov.ph Fort Andres Bonifacio, Tel. No. (632) 810-4831 to 41 Binondo Branch, Tel. No. (632) 241-3494 to 98

Republic of the Philippines
Department of Environment and Natural Resources
NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY
Lawton Avenue, Fort Bonifacio, Taguig City

9 May 2013

Engr. JOEMARIE S. CABALLERO
Chief Science Research Specialist
Data Validation Component
Nationwide DREAM Program

Dear **Engr. Caballero**:

This refers to your letter dated 22 April 2013 requesting clarification regarding the discrepancies in elevations of TGBM tidal benchmarks located at Macabalan Port, Cagayan de Oro City.

Based on our records, TGBM(2007) was established at Macabalan Port in 2007 but was damaged due to developments on port infrastructures and facilities in September 2010. In 2011, the TGBM was re-established to a new location and renamed as TGBM(2011).

If you need any clarifications, please feel free to call Engr. Raul S. Capistrano or Mr. Norelius Baloran at 241-34-94 local 105.

Very truly yours,

Commodore ROMEO I. HO
Director, Hydrography Department

www.namria.gov.ph oss@namria.gov.ph Fort Bonifacio, Tel No. (632)810-4831 to 41 Binondo Branch, Tel No. (632)241-3494 to 98

LEVELS

ACCEPTED RESULTS

DIFFERENCES

B. M. Nos.	First Line	Second Line	Mean	
	Meter	Meter	Meter	
Elevation of (a) above zero of tide staff = 4.0 meters				
(1)–(a)	+0.249	+0.252	+0.251	meters
(2)–(1)	-0.234	-0.235	-0.235	"
(3)–(2)	+0.624	+0.624	+0.624	"
(4)–(3)	-0.042	-0.043	-0.043	"
(5)-(4)	+0.173	+0.173	+0.173	"
(a)-(5)	-0.188	-0.191	-0.190	"
TGBM-C.P.	-1.098	-1.098	-1.098	
T.S.-TGBM	-0.015	-0.015	-0.015	

In taking the differences between bench marks be careful to put the proper + or − sign before each. The algebraic sum of the successive mean differences gives the accepted elevations above zero of tide staff.

@ 4.0m T.S.

ELEVATIONS ABOVE ZERO OF TIDE STAFF

B. M. 1 = 4.251 m ~~feet~~	B. M. 4 = 4.770 m ~~feet~~
~~B. M. 2~~ TGBM = 4.016 m ~~feet~~	B. M. 5 = 4.558 m ~~feet~~
B. M. ~~3~~ 2 = 4.640 m ~~feet~~	B. M. .... feet
B. M. ~~4~~ 3 = 4.597 m feet	B. M. C.P. = 5.113 m ~~feet~~

R. Carmm

R. CAPISTRANO

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DREAM

Disaster Risk and Exposure Assessment for Mitigation