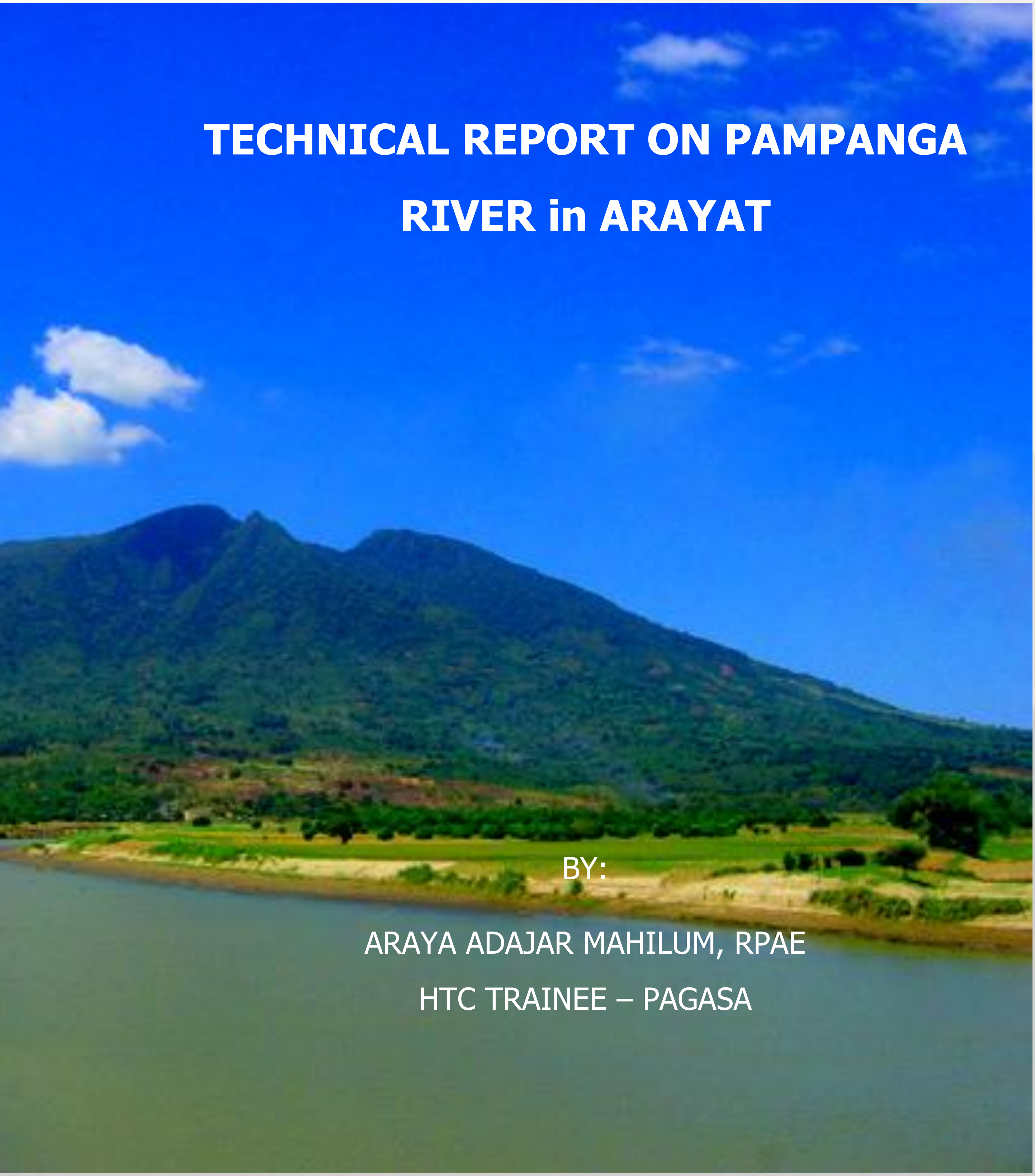

TECHNICAL REPORT ON PAMPANGA RIVER in ARAYAT

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Introduction

The Hydrologist Training Course (HTC) as part of its educational curriculum endeavored sending its trainees for an actual professional field experience. This aimed to improve and substantiate theoretical knowledge into practical applications.

As future hydrologist, Waters above and below the earth surface is considered as the life of the profession. Due to the inherent complexities of studying the waters of the earth all at once, starting with a single river would still be as essential as much. Just like a cup of water, it will not be made possible without each drop.

The actual field experience involved performing four (4) different methods which is the (1) Conventional Current Meter Method (2) Floating Method (3) Slope Area Method and (4) Acoustic Doppler Current Profiler (ADCP) in determining the river cross-section, extent of previous flooding, river velocity and mainly the discharge of Pampanga River in Arayat.

Rivers are important to humans because they supply fresh drinking water, serve as home for important fisheries, provide transportation routes, and are the source for irrigation water and hydroelectric power.

Furthermore, prior knowledge on the status of river physiographic characteristics such as the river profiles, available river cross-sections, and all other data from existing rain gauge and water level stations is of paramount importance in order to efficiently and accurately simulate flooding events when there are impending weather systems that may threaten the river basin thereby inflicting destructive effects to human lives and properties. This information are vital in the issuance of flood advisories and bulletins for effective flood forecasting and warning which entails a great responsibility in ensuring safety of the people as well as reducing or minimizing the impacts if it is impossible to totally avoid these destructions.

Objectives

The general objective of the study is to substantiate theoretical knowledge of the four methods and conduct an actual discharge measurement using the four indirect and direct methods of discharge measurement in the Arayat station of the Pampanga River.

Specifically,

a.) investigate the behaviour of the flooding event in the Arayat Station of Pampanga River; and

b.) compare and contrast the four discharge measurement methods such as the Float, Slope-Area, ADCP and Current Meter Methods in terms of practical applications and advantages and disadvantages.

Study Area: Arayat, Pampanga

Figure 1. Map of Arayat, Pampanga

The Pampanga River is the second largest River in the Island of Luzon, next to Cagayan River and the third largest but most important river in the Philippines. It is located in the Central Luzon region and traverses the provinces of Pampanga, Bulacan, and Nueva Ecija. Its headwaters are located at the Sierra Madre and runs a south and southwesterly course for about 260 kilometers until it drains into Manila Bay.

Figure 2. A View of the Downstream of Pampanga River in Arayat.

Last October 11, 2013, the area experienced severe flooding due to typhoon "Santi" that caused inundation of the flat area upstream and downstream of the bridge. Noticeable traces of high water level marks, debris, silt and loam soils are still present. The riverbed is composed of sand, gravel and a major portion of silt. In the left bank of the river, it is mostly filled with reeds, some trees and grass, while, the right bank is used as plantation with few existing reeds and grass. Banks are silted that when you step on it you will be buried knee high.

1. Methodology

Four Methods of discharge measurement were simultaneously done in the downstream portion of the San Agustin Bridge in Arayat, Pampanga. Details of each method were summarized in the following sections below.

1.1. Float Method

The float method is generally applied for floods which discharge observation by current meter and all other techniques is impractical to use. As the name of the method implies, floats are thrown down into the river and their travelling time in a certain cross section of the river is measured thus, the average velocity in the section can be estimated. This method is the easiest, most practical and cost-effective method for discharge measurements during high flow.

Floats are thrown from bridges but there are emergency cases when they are thrown from the river bank. Float materials used for this study are improvised using bamboo sections of about 1-meter length, filled with 3/4 –full sand with a flag marker for visibility. Travelling time of the float was determined using a stopwatch.

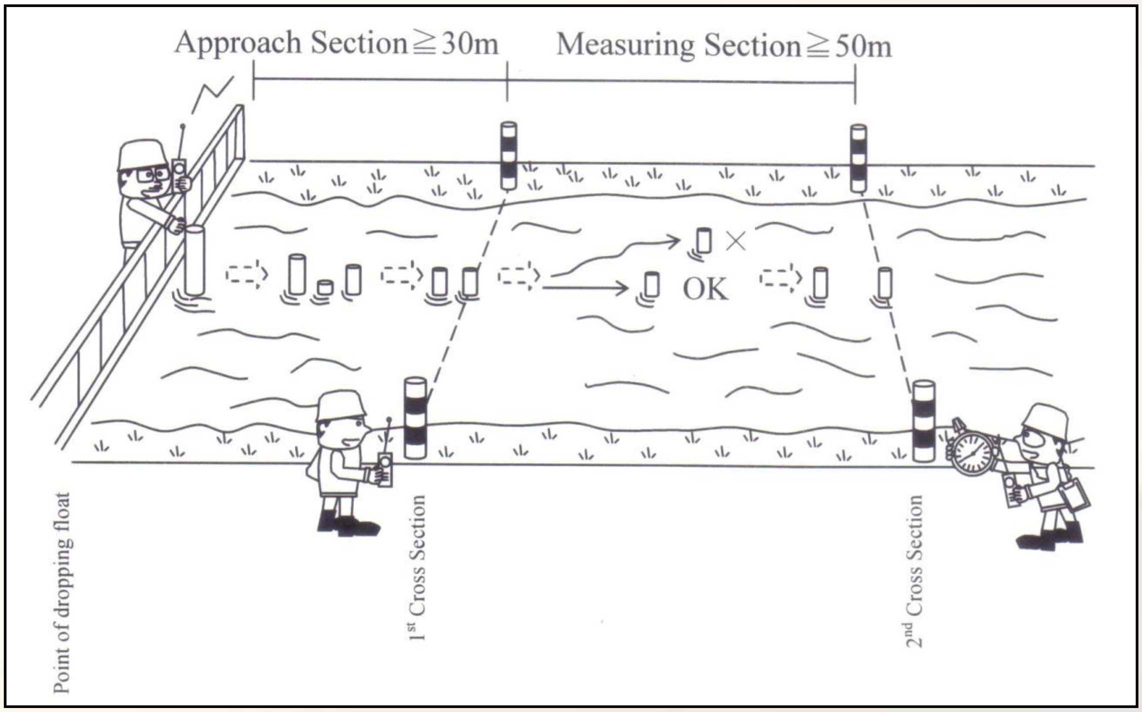


Figure 3. Discharge measurement by float method.

A requirement for this method is a straight section of the river with enough length consisting of approach section and measurement section. The approach section is from dropping point to the first cross section which requires at least 30-meter distance in order to enable a float to maintain its draft. The measurement section is from the first cross section to the second cross section in order to measure the travelling time of a float which requires at least 50 meters. However, in practice, the distance is determined by the maximum velocity multiplied by 10-15 seconds. In Japan, distances ranging from 50 to 100 meters are popular. Too long section causes error in measurement due to variation of stage for long travelling time.

Since discharge observation by float is conducted during high floods, it is difficult to measure water depth simultaneously thus, only water level is measured during discharge observation by float and cross section survey is conducted to estimate discharge area soon after the flood.

In the duration of the fieldwork activity, the two cross sections were measured by boat method using an echo sounder to record water depth and a range-finder to determine the distance of every vertical reckoned from the water edge. Water levels upon the start of observation and at the end were noted to be used to estimate the discharge area of each cross-section using the equation $Q_i = V_i \times A_i$.

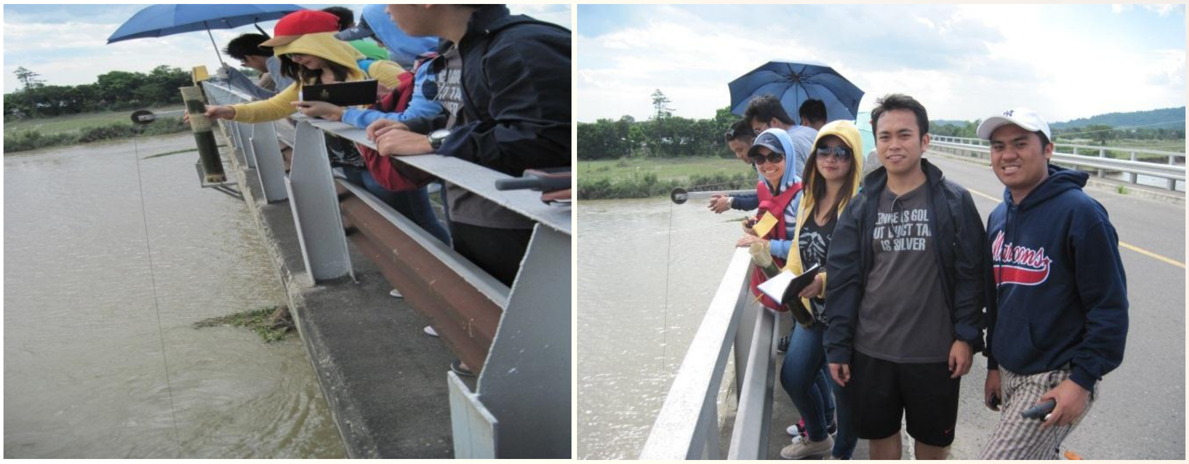


Figure 4. During Floating Method In San Agustin Bridge Arayat, Pampanga.

1.2. Slope-Area Method

The slope-area method consists of using the slope of the water surface in a uniform reach of channel and the average cross-sectional area of that reach to give a rate of discharge. The discharge may be computed from the Manning formula:

$$Q = (1.486/n)\ A\ R_h^{2/3}\ S^{1/2}$$

where:

Q = discharge (m^3/s)

A = mean area of the channel cross section (m^2)

R_h = mean hydraulic radius of the channel (m)

σ = energy slope of the flow

n = a roughness factor depending on the character of the channel lining

A fairly straight reach of the channel should be chosen with length of equal or greater than 75 times the mean water depth and is a contracting area. If the reach is free of rapids, abrupt falls, or sudden contractions or expansions, then the water surface slope is the same as the energy slope.

Figure 5. Fairly straight river reach

The slope, σ, or the fall may be determined by dividing the difference in the water surface elevations at the two ends of the reach represented by the high water marks in cross sections 1 and 3 by the total length of the reach. A value of greater than or equal to 0.15 or greater than or equal to the velocity head should be attained.

The hydraulic radius, R_h, is defined as the area of the cross section divided by its wetted perimeter. Where the channel or canal is of regular cross section, and the depths at the ends of the course are equal, the area and the wetted perimeter will be constant through-out the course. In irregular channels, the area and the wetted perimeter at several cross sections will be required, and a mean value will be used in computing the hydraulic radius.

The factor, *n*, depends on the character of the channel. It may vary from 0.010, where conditions approaching the ideal are maintained, to 0.060, where the channel is strewn with stones and debris or is about one-third full of vegetation.

Because the proper selection of the roughness factor, *n*, for many streams is difficult and is, at best, an estimate, the discharge determined by the slope-area method is only approximate. Care must be taken to determine the slope and areas simultaneously if the water levels are changing.

Using the total station, the benchmark (BM) in the old station at the left bank upstream of the Pampanga River was used. The known elevation of 9.114 meters was used to start with the measurements. In this study, a total of 36 Tie Points and 5 BM Backsights were measured taking off from the known elevation in the benchmark to the three cross sections for this method. The following equations were used to compute for the elevations of each TP and the Height of the Instrument. Several readings taken from the total station used were the Vertical Distance (VD), Horizontal Distance (HD) and Horizontal Angle (HA).

$$HI = BM + \text{Height of Prism Rod} - BS$$

$$\text{Unknown Elevation} = HI + FS - \text{Height of Prism Rod}$$

where: HI = height of Instrument
BM = Benchmark Elevation
BS = Back Sight (VD)
FS = Fore Sight (VD)

For easy computations, an excel suite provided by the PRFFWC for automatic discharge computation by slope-area method was provided.

1.3. Acoustic Doppler Current Profiler Method

In recent years, advances in technology have allowed the USGS to make discharge measurements by use of an Acoustic Doppler Current Profiler (ADCP). An ADCP uses the principles of the Doppler Effect to measure the velocity of water. The Doppler Effect is the phenomenon we experience when passed by a car or train that is sounding its horn. As the car or train passes, the sound of the horn seems to drop in frequency.

The ADCP uses the Doppler Effect to determine water velocity by sending a sound pulse into the water and measuring the change in frequency of that sound pulse reflected back to the ADCP by sediment or other particulates being transported in the water. The change in frequency, or Doppler Shift, that is measured by the ADCP is translated into water velocity. The sound is transmitted into the water from a transducer to the bottom of the river and receives return signals throughout the entire depth. The ADCP also uses acoustics to measure water depth by measuring the travel time of a pulse of sound to reach the river bottom at back to the ADCP.

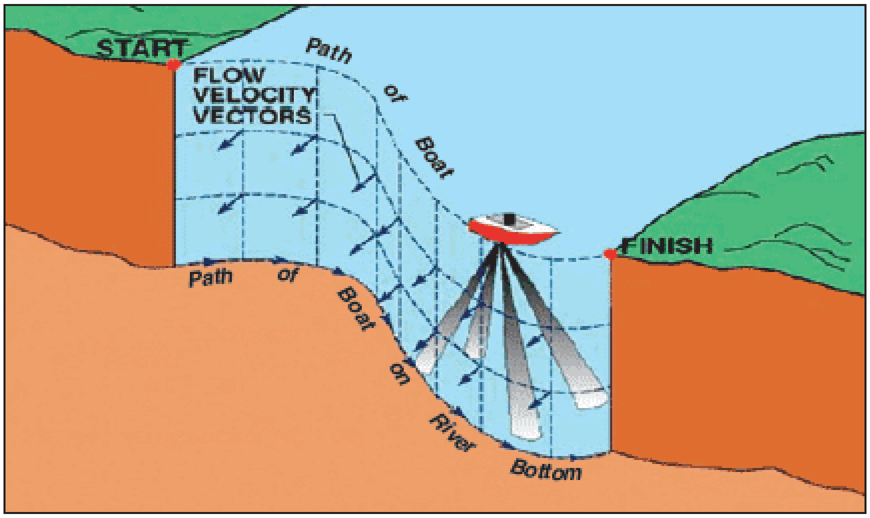


Figure 6. The ADCP Principle of discharge measurement

To make a discharge measurement, the ADCP is mounted onto a boat or into a small watercraft with its acoustic beams directed into the water from the water surface. The ADCP is then guided across the surface of the river to obtain measurements of velocity and depth across the channel. The river-bottom tracking capability of the ADCP acoustic beams or a Global Positioning System (GPS) is used to track the progress of the ADCP across the channel and provide channel-width measurements. Using the depth and width measurements for calculating the area and the velocity measurements, the discharge is computed by the ADCP using discharge = area x velocity, similar to the conventional current-meter method. Acoustic velocity meters have also been developed for making wading measurements.

The World Meteorological Organization (WMO) guide to stream gauging using ADCP suggests four transects to be measured at certain distances. For this study, a total of eight transects were measured at varying distances estimated from each transect.

1.4. Current Meter Method

The most common method used by the USGS for measuring discharge is the mechanical current-meter method. In this method, the stream channel cross section is divided into numerous vertical subsections. In each subsection, the area is obtained by measuring the width and depth of the subsection, and the water velocity is determined using a current meter. The discharge in each subsection is computed by multiplying the subsection area by the measured velocity. The total discharge is then computed by summing the discharge of each subsection.

Numerous types of equipment and methods are used by USGS personnel to make current-meter measurements because of the wide range of stream conditions throughout the United States. Subsection width is generally measured using a cable, steel tape, or similar piece of equipment. Subsection depth is measured using a wading rod, if conditions permit, or by suspending a sounding weight from a calibrated cable and reel system off a bridge, cableway, or boat or through a hole drilled in ice.

Figure 7. Current meter method by boat

For this study, current meter measurements were taken using the boat method. The Price AA current meter was used with a sounding reel loaded in the boat. Since the water level is significantly low compared from the high flow during the first day of fieldwork, a one point method was used – which is 0.6 from the water surface. Several verticals were measured guided with a tagline to ensure a relatively straight cross section. The calibration equation to be used will be:

$$V = 0.702N + 0.013$$

1.5. Rating Curve

If a measurement of the flow is made by the current-meter method on different occasions when the river is flowing at different depths, these measurements can be used to draw a graph of amount of flow against depth of flow. The depth of flow of a stream or river is called stage, and when a curve has been obtained for discharge against stage, the gauging station is described as being rated. Subsequent estimates of flow can be obtained by measuring the stage at a permanent gauging post, and reading off the flow from the rating curve. If the cross-section of the stream changes through erosion or deposition, a new rating curve has to be drawn up. To plot the rating curve, it is necessary to take measurements at many different stages of flow, including infrequently occurring flood flows. Clearly this can take a long time, particularly if access to the site is difficult, so it is preferable to use some type of weir or flume which does not need to be individually calibrated, and these are discussed in later sections.

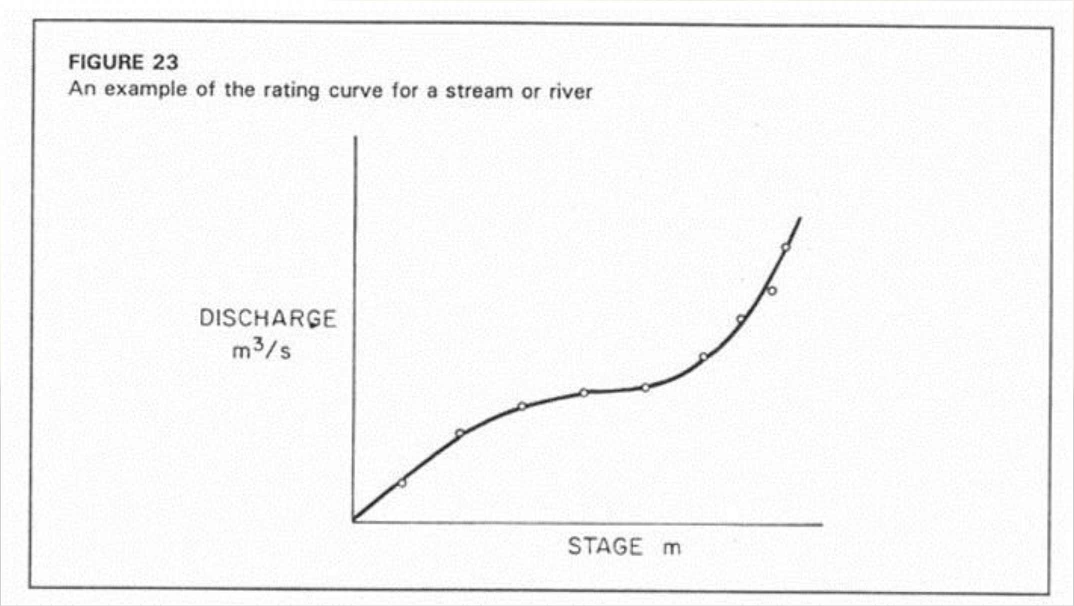


Figure 8. Rating curve

2. Results and Discussion

Results of the study from the four different discharge measurement methods were summarized in the following tables below.

Table 1. Summary of measurements for the Float Method.

Station	Time (s)	Distance (m)	Velocity (m/s)	Cross Section 1			Cross Section 2		
				HD (m)	Depth (m)	Q (cms)	HD (m)	Depth (m)	Q (cms)
0				0.0			0.0		
1	129	100	0.775	61.0	4.3	136.67	63.0	4.9	159.53
2	106	100	0.943	82.0	6.4	102.64	84.0	6.0	127.36
3	75	100	1.333	95.0	9.2	202.40	108.0	7.0	182.00
4	100	100	1.000	115.0	11.6	208.80	123.0	7.6	117.80
5	125	100	0.800	131.0	7.2	112.32	139.0	6.9	126.96
6				154.0			169.0		
Total						**762.83**			**713.65**
Average						**738.24**			

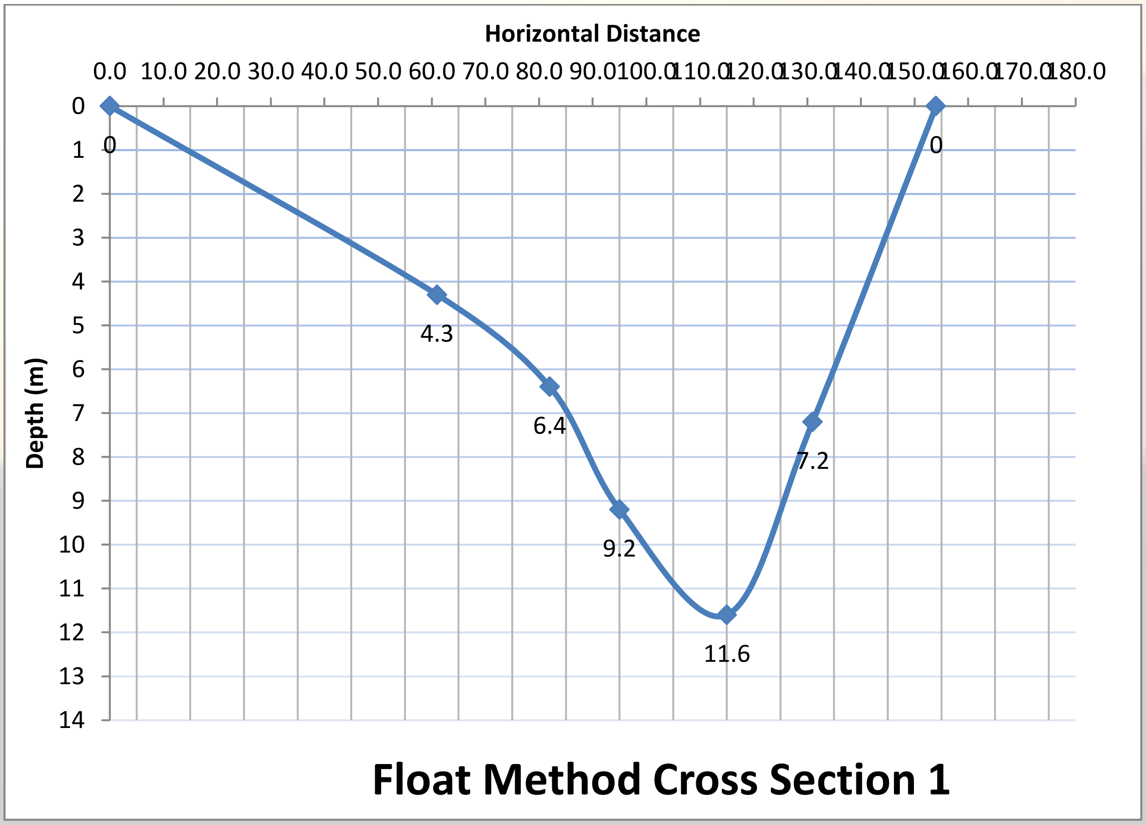


Figure 9. Float Cross Section 1 Profile

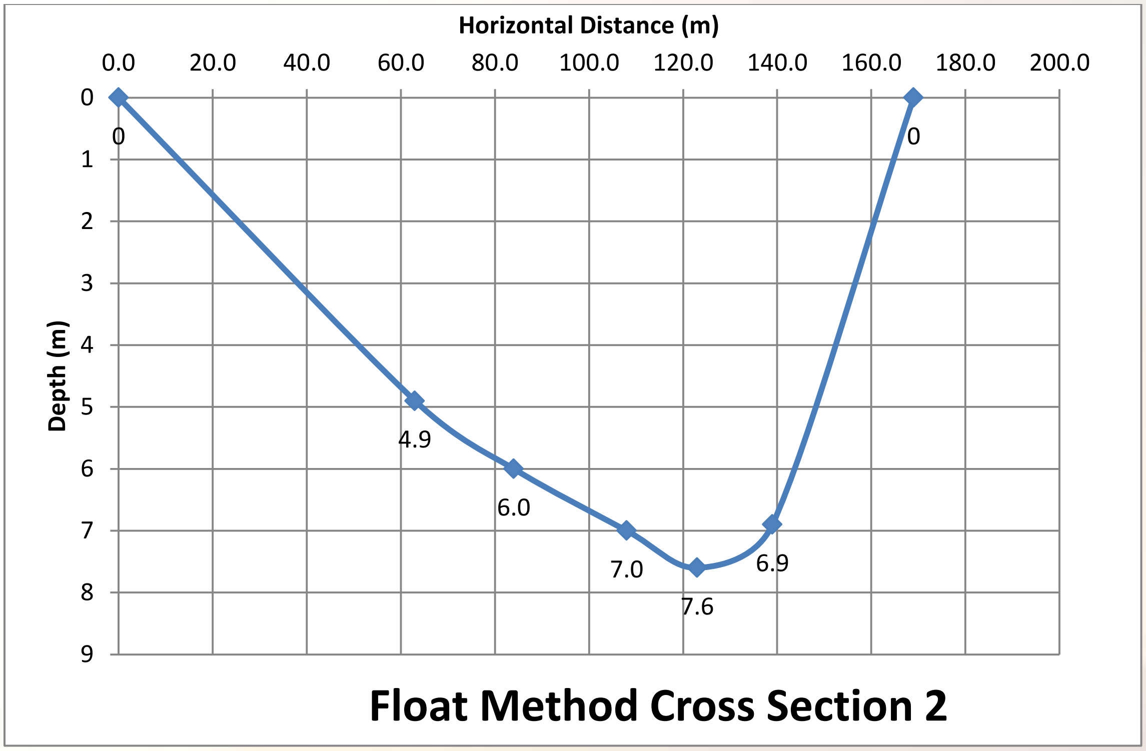


Figure 10. Float Cross Section 2 Profile

Table 2. Summary of measurements for the Slope-Area Method.

Station	VD (m)	HA (deg-min-sec)	HD (m)	Elevation m)	Remarks
BS1	0.776	24° 34' 00"	8.642	9.538	
TP1	-0.792	225° 45' 20"	209.487	7.546	
BS2	-0.586	119° 20' 20"	37.278	9.332	
TP2	0.142	233° 09' 20"	104.74	8.274	HWM1 RB
TP3	-0.526	248° 45' 20"	35.468	7.606	
TP4	0.326	247° 59' 00"	11.93	8.458	
TP5	0.197	107° 14' 00"	19.707	8.329	
TP6	-0.889	84° 18' 40"	50.677	7.243	
BS3	0.68	293° 30' 90"	7.821	5.658	
TP8	-1.735	78° 04' 20"	103.399	5.848	
TP9	-3.018	77° 58' 00"	109.198	5.131	RB WE1
TP10	1.192	79° 50' 40"	284.873	3.848	HWM1 LB
TP7	-1.018	82° 34' 00"	77.728	8.066	
TP11	0.906	79° 51' 20"	212.274	7.772	
TP12	-0.743	80° 06' 40"	201.579	6.123	
TP13	-3.057	80° 22' 40"	199.509	3.809	LB WE1
BS4	0.263	350° 48' 00"	108.521	8.483	
TP14	-1.12	80° 14' 20"	96.287	3.763	RB WE2
TP15	-0.996	69° 56' 00"	93.386	6.287	
TP16	-3.421	72° 10' 20"	243.28	3.862	LB WE2
TP17	1.092	72° 37' 20"	250.296	8.375	

TP18	-0.746	70° 34' 40"	87.386	6.537	
TP19	0.539	73° 21' 00"	302.738	7.822	HWM2 LB
TP20	-0.663	69° 50' 40"	67.002	6.62	
TP21	0.083	61° 13' 00"	26.601	7.366	
TP22	-0.041	20° 11' 40"	8.162	7.242	
TP23	1.039	290° 51' 20"	16.994	8.322	
TP24	0.973	255° 05' 20"	38.451	8.256	HWM2 RB
BS5	0	351° 28' 20"	277.511	8.746	
TP25	-0.867	91° 02' 00"	100.313	4.279	RB WE3
TP26	-3.41	91° 21' 40"	249.356	4.136	LB WE3
TP27	-1.507	90° 42' 00"	97.097	6.039	
TP28	0.788	87° 36' 20"	290.393	7.534	HWM3 LB
TP29	-1.098	91° 01' 20"	257.446	6.448	
TP30	-0.845	92° 00' 00"	93.696	6.701	
TP31	-0.379	100° 18' 20"	53.608	7.167	
TP32	0.1	122° 52' 40"	9.815	7.646	
TP33	-0.018	238° 39' 40"	15.247	7.528	
TP34	0.94	256° 58' 40"	19.332	8.486	
TP35	1.26	267° 08' 40"	45.271	8.806	
TP36	1.086	267° 33' 20"	94.086	8.632	HWM3 RB

Table 3. Summary of measurements for the ADCP.

Transect	**Discharge (Q in cms)**
1	292.871
2	292.668
3	304.15
4	334.503
5	250.691
6	238.568
7	296.384
8	301.213
Average	**288.881**

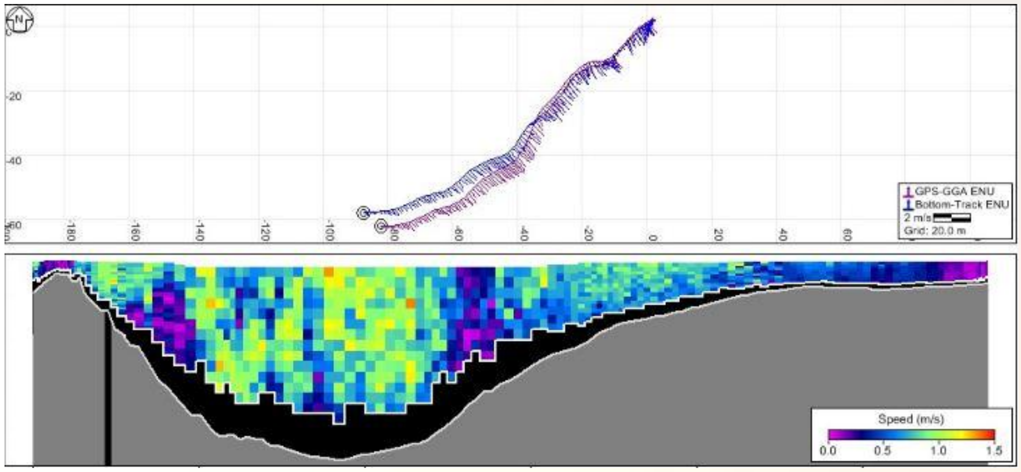


Figure 11. Transect 1 of ADCP Method

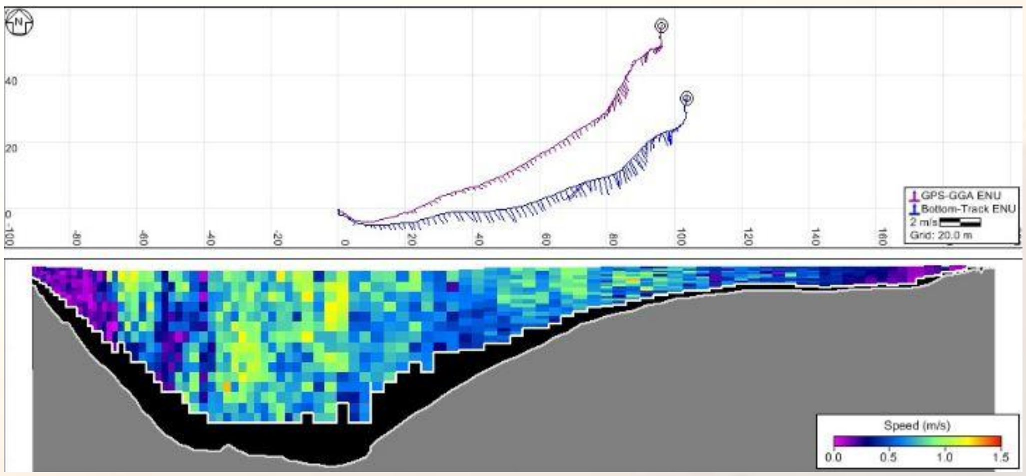


Figure 12. Transect 2 of ADCP Method

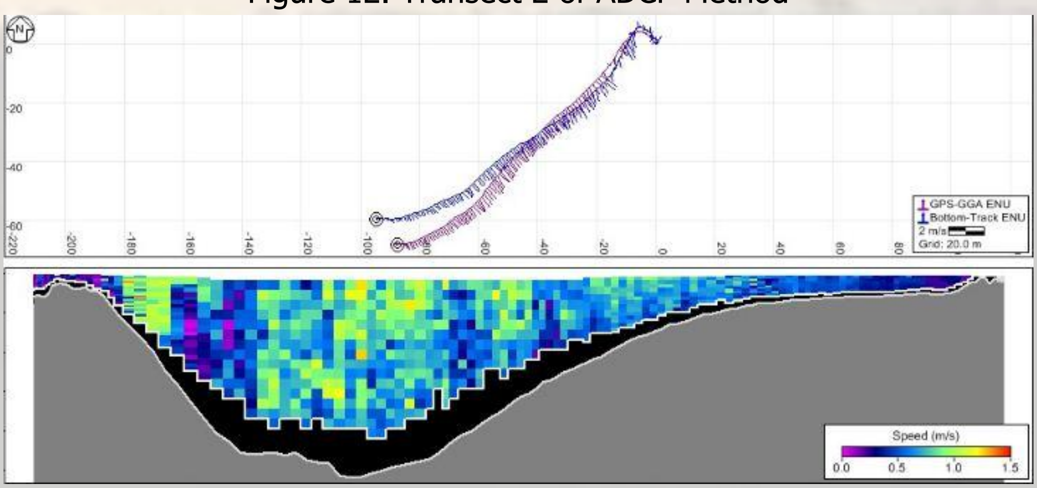


Figure 13. Transect 3 of ADCP Method

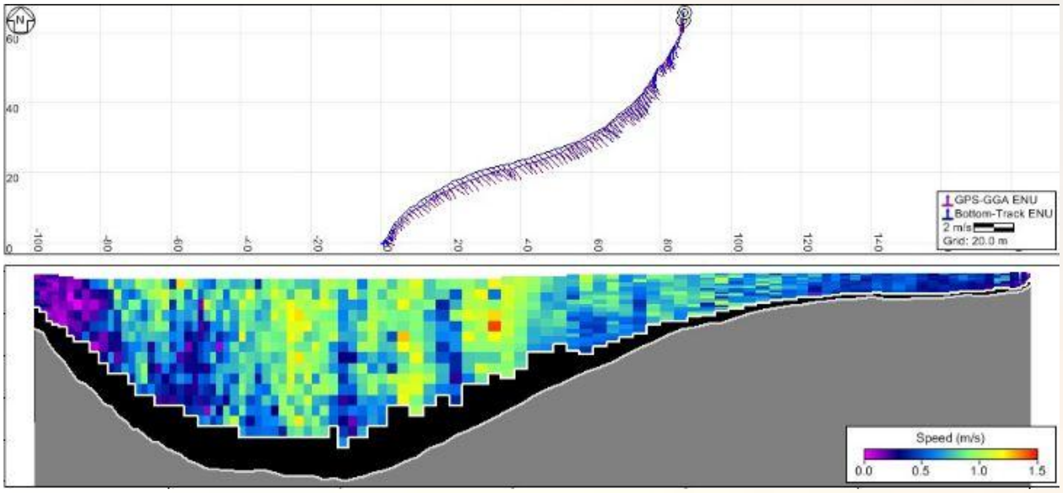


Figure 14. Transect 4 of ADCP Method

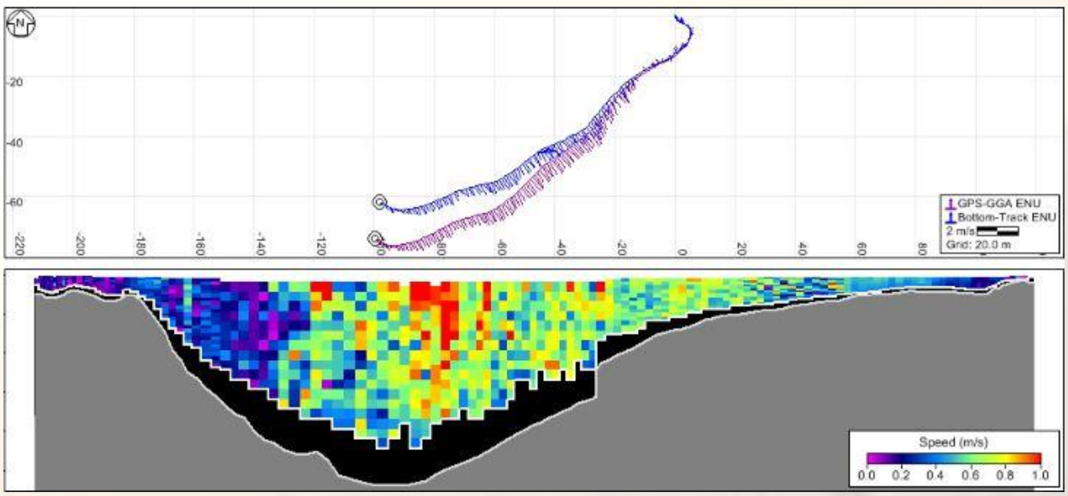


Figure 15. Transect 5 of ADCP Method

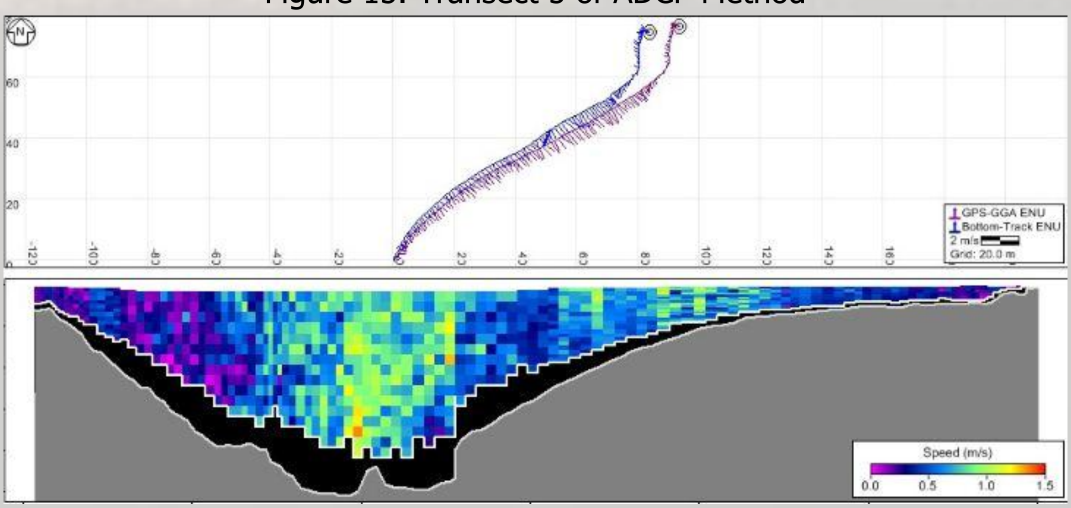


Figure 16. Transect 6 of ADCP Method

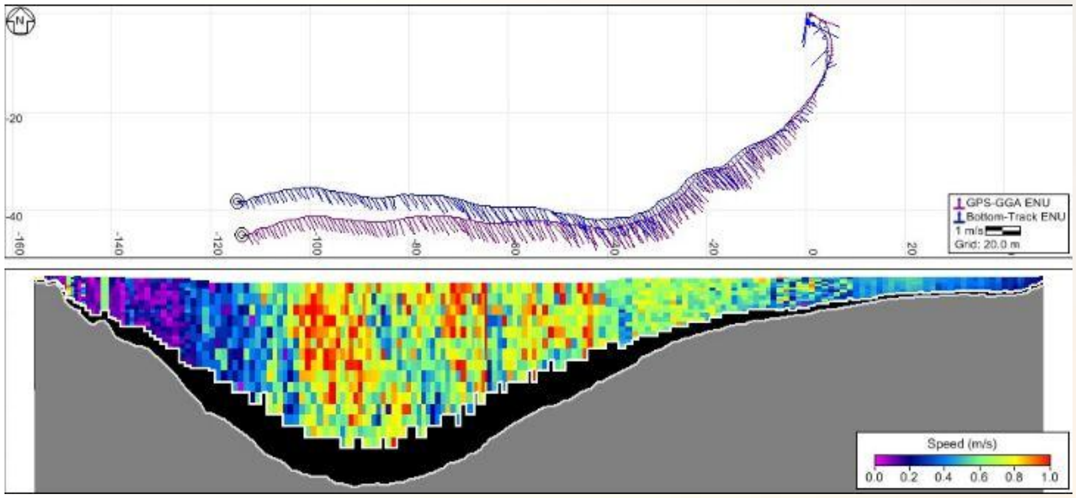


Figure 17. Transect 7 of ADCP Method

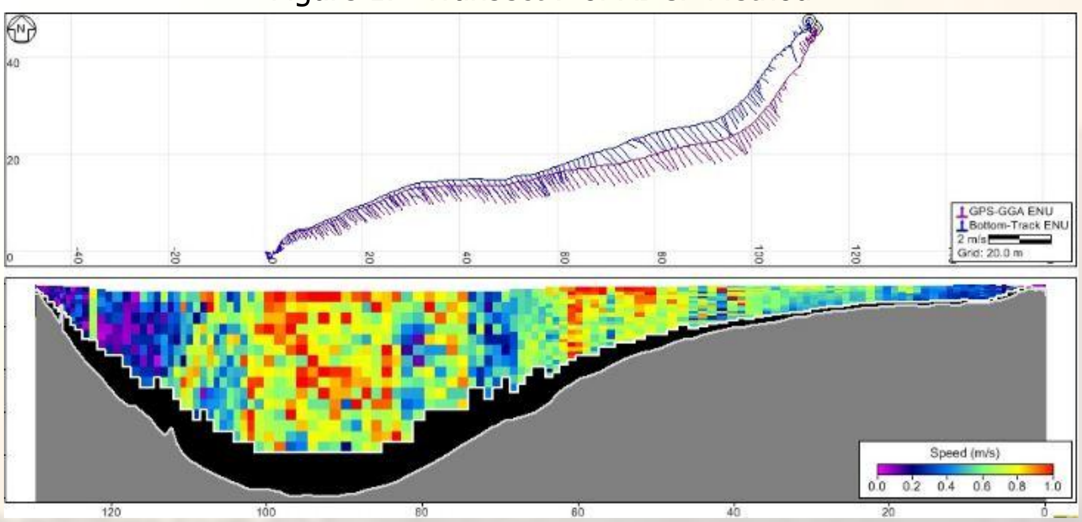


Figure 18. Transect 8 of ADCP Method

The ADCP has several salient points which make discharge measurement fast and easy. In the past, measuring the current depth profile required the use of long strings of current meters but this is no longer needed as ADCP measures small scale currents. Unlike previous technology, ADCPs measure the absolute speed of the water, not just how fast one water mass is moving in relation to another. It measures a water column up to 1000m long.

However, it also presents disadvantages such as a.) High frequency pings yield more precise data, but low frequency pings travel farther in the water. So scientists must make a compromise between the distance that the profiler can measure and the precision of the measurements; b.) ADCPs set to "ping" rapidly also run out of batteries rapidly; c.) If the water is very clear, as in the tropics, the pings may not hit enough particles to produce reliable data; d.) Bubbles in turbulent water or schools of swimming marine life can cause the instrument to miscalculate the current; and e.) Users must take precautions to keep barnacles and algae from growing on the transducers.

Table 4. Summary of measurements for the current meter method.

Station	**Distance from Left Water Edge (m)**	**Water Surface Depth (m)**	**0.6 Depth (m)**	**Velocity**	
				No. of Revolutions	**Time (sec)**
1	1	NA	NA	Unable	60
2	6	1	0.4	Unable	60
3	9	2.1	0.84	Unable	60
4	12	3.17	1.268	Unable	60
5	16	4.7	1.88	1	60
6	21	6	2.4	6	61
7	26	6.8	2.72	10	61
8	31	8.1	3.24	10	61
9	36	8.6	3.44	13	62
10	41	8.11	3.244	8	63
11	46	8.05	3.22	5	65
12	51	7.4	2.96	9	75
13	56	6.5	2.6	5	30
14	61	5.42	2.168	1	45
15	66	3.62	1.448	7	66
16	71	2.75	1.1	Unable	60
17	76	1.8	0.72	Unable	75
18	81	0.9	0.36	NA	NA
19	86	0.35	0.14	NA	NA
20	98.3	NA	NA	NA	NA

3. Summary and Conclusions

Indirect and direct methods of discharge measurement have their limitations and strengths depending on the practical use of each during flood and non-flood seasons. For the float method, it is the most practical and most effective method for peak discharge determination when all other methods are impossible to be performed.

On the other hand, the slope – area method, a tedious and iterative method provides good information on the discharge of the streams given accurate instruments.

Meanwhile, the ADCP has proven to be beneficial to stream gauging in several ways. The use of ADCPs has reduced the time it takes to make a discharge measurement. The ADCP allows discharge measurements to be made in some flooding conditions that were not previously possible. Lastly, the ADCP provides a detailed profile of water velocity and direction for the majority of a cross section instead of just at point locations with a mechanical current meter; this improves the discharge measurement accuracy.

4. Future Developments

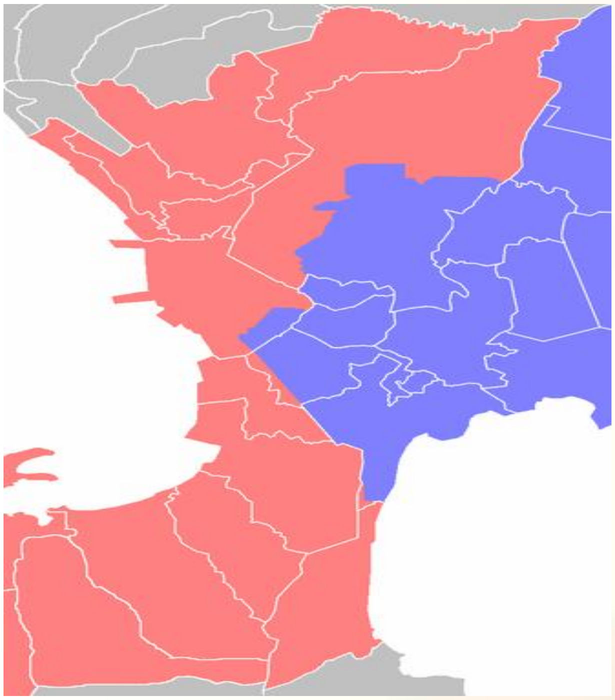
Problems were encountered and there were deviations from the standard specifications of each method as expected. Results of this study may not provide very accurate results given some limitations on the conduct of the activity. Thus, comparison of the results in this study can be verified or cross-referenced with the information available at the PRFFWC. The use of materials under standard specifications for this activity can be improved in future similar hydrographic survey to ensure optimal results. Proper calibration of equipment is likewise recommended.

5. Travel Insights

The visits to the actual field have stimulated interest and inquiry for the trainees, which has provided new insights, information and knowledge that, cannot be adequately developed through regular classroom instruction.

5.1 LA MESA DAM

BRINGING FRESH INSIGHTS to THE SURFACE



The water collected in the reservoir is treated on-site by the Maynilad Water Services, and at the Balara Treatment Plant further south by the Manila Water. Both water companies are private concessionaires awarded by the Metropolitan Waterworks and Sewerage System, the government agency in charge of water supply. It is a vital link to the water requirements of 12 million residents of Metro Manila considering that 1.5 million liters of water pass through this reservoir every day. It is also the last forest of its size in the metropolis.

Metro Manila and its surrounding areas are divided into two water concessionaires: Maynilad Water (red) and Manila Water (blue)

5.2 PANTABANGAN DAM

DISCOVERING WONDERS OF CREATING POWER

The dam is a 107 m (351 ft) tall and 1,615 m (5,299 ft) long embankment-type with 12,000,000 cu yd (9,174,658 m^3) of homogeneous earth-fill and an impervious core. The crest of the dam is 12 m (39 ft) wide while the widest part of its base is 535 m (1,755 ft). The dam's crest sits at an elevation of 232 m (761 ft) and is composed of three sections: the main dam, a saddle dam, and an auxiliary dam located with the spillway. The power house is located at the base of the main dam and contains two

50 MW Francis turbine-generators for an installed capacity of 100 MW. Each turbine receives water via a 6 m (20 ft) diameter penstock. When the water is discharged, it is released into a 250 m (820 ft) long tailrace channel where it re-enters the river.

5.3 CONG DADONG DAM

EXPLORING SOURCES OF LIFE

The P3.4-billion Cong Dadong Dam, has been designed to irrigate 10,270 hectares of farms in seven eastern towns, feeds only some 3,500 ha despite a slight surplus amid the long dry spell in Luzon. The dam, named after President Macapagal-Arroyo’s father, the late President Diosdado Macapagal.

5.4 ANGAT DAM

EMPOWERING INSIGHTS

Angat Dam is a concrete water reservoir embankment hydroelectric dam that supplies the Manila metropolitan area water. It was a part of the Angat-Ipo-La Mesa water system. The reservoir supplies about 90 percent of raw water requirements for Metro Manila through the facilities of the Metropolitan Waterworks and Sewerage System and it irrigates about 28,000 hectares of farmland in the provinces of Bulacan and Pampanga.

5.5 LEARNING AND LIFE

ESTABLISHING STRONG CAMARADERIE

LEARNING FROM MENTORS

HAVING FUN BUT STILL LEARNING ☺

6. Acknowledgement

This fieldwork activity would not be possible without the help and guidance of the PRFFWC and HMD personnel who assisted in the proper conduct of the four discharge measurements.

7. References

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