Technical Report on
Stream Gauging entitled:

Methods of Discharge Measurement in Arayat Station of the Pampanga River

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1. Introduction

Discharge is one of the key inputs in getting the rating curve of a certain stream. It is defined as the volume of water moving down a stream or river per unit time, commonly expressed in cubic meters per second. Stream discharge is computed by multiplying the cross-sectional area of water in a channel by the average velocity of the water in that cross-section.

The Philippines is experiencing a lot of weather hazards that causes lost of life and damage to properties. Moonsoons, typhoon, coldfront are some of the hazards that come across the country. Typhoon for example, an average of 20 passes over the Philippine Area of Responsibility annually.
Most of these weather hazards are associated with rain. Excessive rainfall causes significant impact on a certain society when the stream stage rise. Stream stage is important that it can be used to compute stream discharge at any instant.

So why are we that interested of religiously getting the discharge measurements including the cross-sections of the river? To come up with a rating curve and rating equation to know the relationship between stage and discharge at a river cross-section. It is important to keep the rating curves up to date so that flood forecasts are consistent and as accurate as possible.

2. Background

As part of the requirements in the subject Stream Gauging, the author developed a fieldwork report entitled:

Methods of Discharge Measurement
in Arayat Station of the Pampanga River

3. Objectives

The study conducted is guided with the general aim to conduct and fully understand an actual stream gauging or discharge measurement and to implement four methods of discharge measurements in Arayat Station of the Pampanga River.

Specifically, the author seeks to:

- Compare and contrast the four discharge measurement methods such as Float Method, Slope-Area Method, Current Meter Method and using the Acoustic Doppler Current Profiler (ADCP) in terms of practical applications, advantages and disadvantages.
- Compilation of data gathered from the methods of discharge measurement and be able to come up with a rating curve and a rating equation for the Arayat Station.
- Analyze and explain results from the gathered data, its effects of the variations, discrepancy and consistency.

4. Study Area

Arayat is a first class municipality in the province of Pampanga. According to the 2010 census, it has a population of 121, 348 people. A large portion of the Mount Arayat is located within this municipality. The actual location is at Barangay San Agustin, Arayat with the San Agustin Bridge as the reference landmark taking into consideration the existence of the benchmark in the old station at the left bank upstream of the bridge and the new unmanned telemetered station located at the other end of the bridge.

Figure 1. A view of Mt. Arayat from the bridge

Figure 2: San Agustin Bridge

5. Methodology

During the ten-day fieldwork, four methods of discharge measurement were done within the vicinity of the Arayat Station in Arayat, Pampanga. Actual details of each method for data collection are summarized below.

5.1 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.

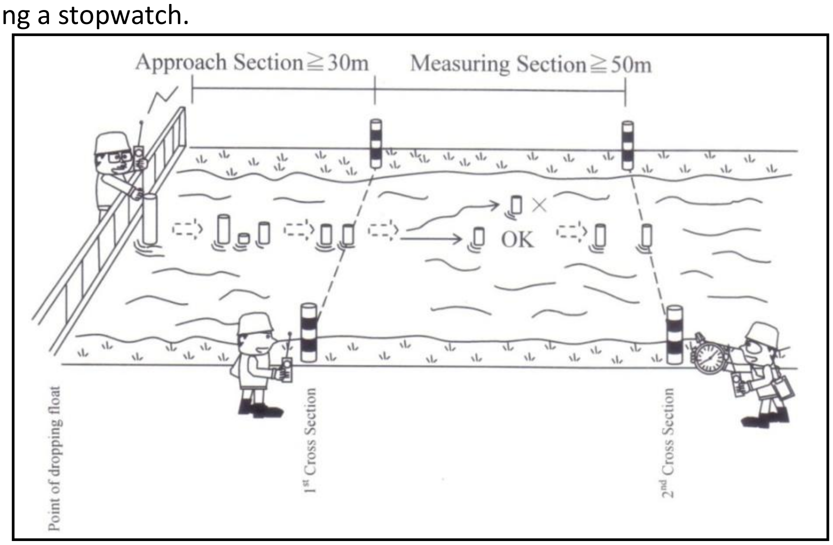

Figure 3. Discharge measurement by float method

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 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 Qi = Vi x Ai.

5.2 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:

$$Q = (1.486/n)AR_h^{2/3}S^{1/2}$$

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.

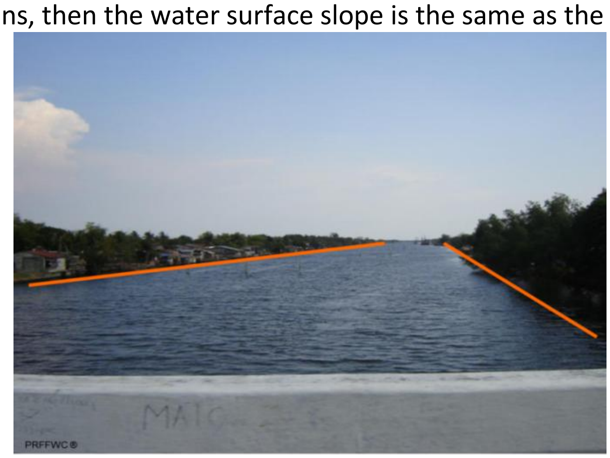

Figure 4. Fairly straight river reach

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 + Height of Prism Rod – BS
Unknown Elevation = HI + FS – 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.

5.3 Acoustic Doppler Current Profiler (ADCP) 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.

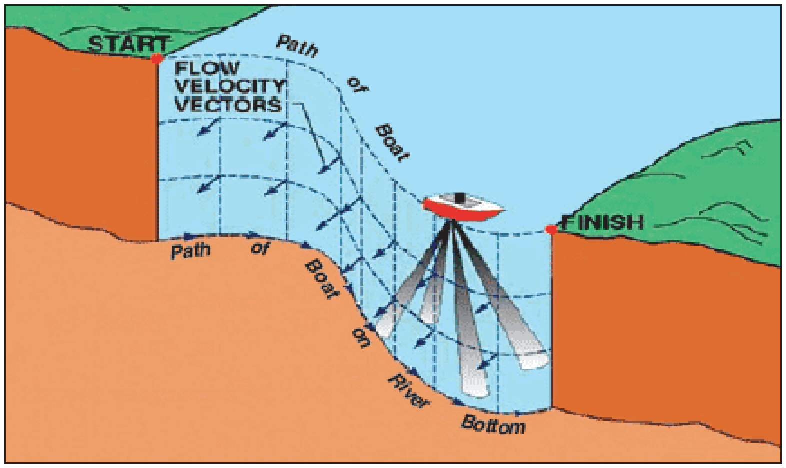

Figure 5. ADCP Principle of discharge measurement

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.

5.4 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 6. 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 0.6D 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:

$$V = 0.702N + 0.013$$

5.5 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.

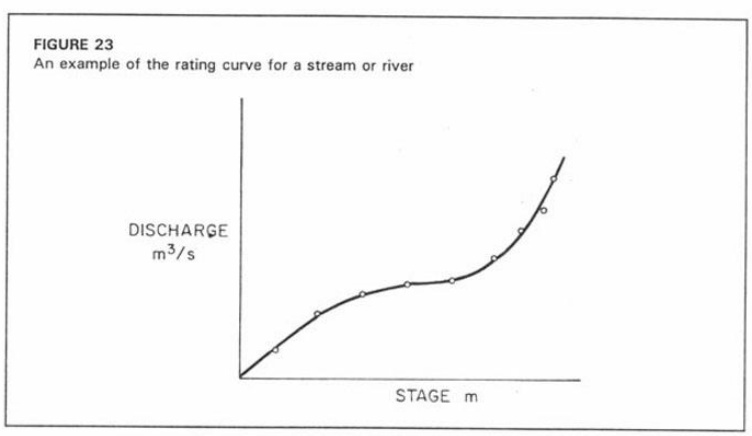

Figure 7. Rating curve

6. Results and Discussion

Results of the study from the four different discharge measurement methods were summarized in the following tables below after all the data has been collected, integrated and analyzed.

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	**Mid-section method was used to compute for Q**					**762.83**			**713.65**
Average						**738.24**			

An average of 738.24 cu.m. per second was computed in Float Method, the first method that we are tasked to perform. The water level is relatively high during the actual measurement. The cross-sections were plotted as shown in the figures below. The deepest portion in the first cross-section measures 11.6m. while 7.6m in the second cross-section.

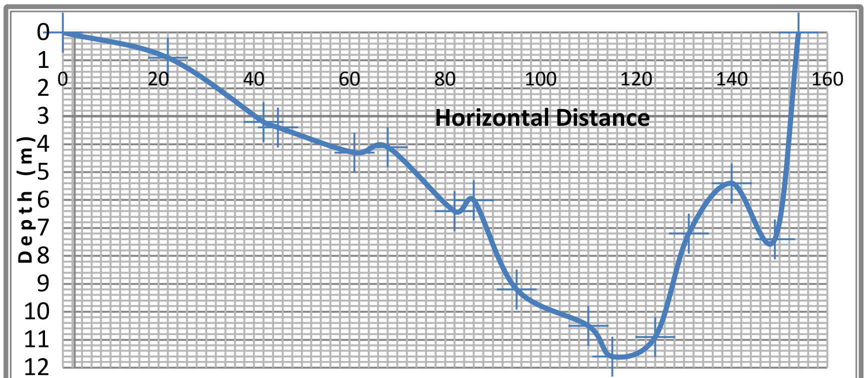

Figure 8. Float Method Cross-section 1 Profile

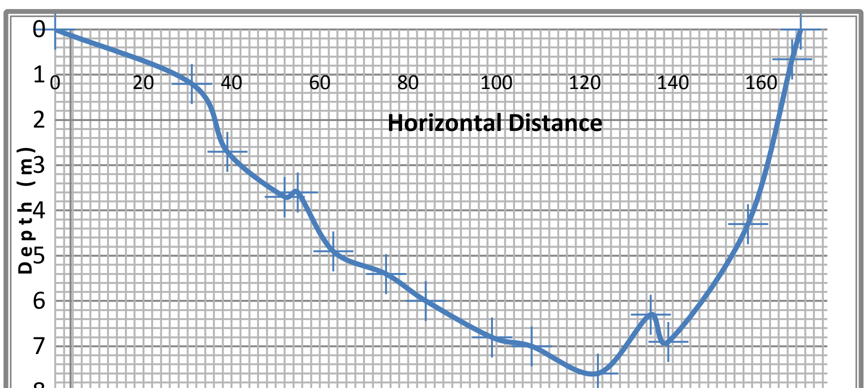

Figure 9. Float Method Cross-section 2 Profile

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	8.066	
TP8	-1.735	78˚ 04' 20"	103.399	5.131	
TP9	-3.018	77˚ 58' 00"	109.198	3.848	RB WE1
TP10	0.713	79˚ 50' 40"	284.873	7.579	HWM1 LB
TP7	-1.018	82˚ 34' 00"	77.728	5.848	
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	0.96	267˚ 08' 40"	45.271	8.506	
TP36	0.683	267˚ 33' 20"	94.086	8.229	HWM3 RB

The slope area measurements were summarized in Table 2. It appears that the highest water elevation during the flood caused by Typhoon Santi was 8.274 meters at the right bank of the first cross-section. Below are the cross-sections plotted inputing all the required details in the Excel Suite given.

Republic of the Philippines
Department of Science and Technology
PHILIPPINE ATMOSPHERIC, GEOPHYSICAL AND ASTRONOMICAL SERVICES ADMINISTRATION (PAGASA)
Pampanga River Flood Forecasting and Warning Center (PRFFC)
Agham Road, Diliman, Quezon City

FFB, PAGASA **Slope-Area Summary Sheet (3-Section)**

Station:	*Arayat*	River:	*Pampanga River*
Flood Date:	*13-Oct-13*	Drainage Area:	
Gauge Height:		Meas. #:	

X - Section Properties:

X-Sect.	Width	Area	Highwater Marks Left Bank	Right Bank	Average Water Sfc.	d_m (mean depth)	n	r	K	K^3/A^2	α	F	State of Flow
1	146.00	2056.71	7.579	8.274	7.9265	14.087	0.03	13.84	398751.9	1.5E+10	1	0.099	tranquil
2	172.00	1525.85	7.822	8.256	8.039	8.871	0.03	8.83	218797.6	4.5E+09	1	0.168	tranquil
3	180.00	1676.52	7.534	8.229	7.8815	9.314	0.03	9.24	247827.2	5.4E+09	1	0.149	tranquil

note: Assume no sub-divided sections, hence α is always 1!!

Reach Properties:

Reach	Length	Δh Fall	k	reach condition	K_U/K_D	K_U/K_D Condition	Ave. A	Q by formula	Ave V
1-2	100	-0.1125	0	contracting	1.822469	poor	1791.280	x	x
2-3	200	0.1575	0.5	expanding	0.882863	good	1601.182	9334.831	5.830
1-2-3	300	0.045	0	contracting	1.608991	poor	1753.026	**2389.701**	1.363

n - roughness coefficient
K - conveyance
K_w - wtd. conveyance (Geometric mean of K of 2 sections).
F - Froude no.(indicates the state of flow).
α - velocity head coefficient
r - hydraulic radius
k - coefficient for differences in velocity heads between 2 sections.
h_v - velocity head
h_f - energy loss due to boundary friction in the reach.
S - friction slope

Discharge Computation:(comparison)

Reach	Assumed Q	h_v U/S	D/S	Δh_v	h_f	$S=h_f/L$	$S^{1/2}$	K_w	Computed Q
1-2	x	0.068878	0.125144	-0.05627	-0.16877	-0.00169	x	295374.2	x
2-3	9334.831	0.125144	0.103661	0.021483	0.168241	0.000841	0.029004	232860.5	6753.786

Rem:

$Q_{1\text{-}2\text{-}3}$ = 2389.70 **cumecs**

Discharge

Figure 10. Excel suite for the slope area

Total Area = 2056.71 meters^2

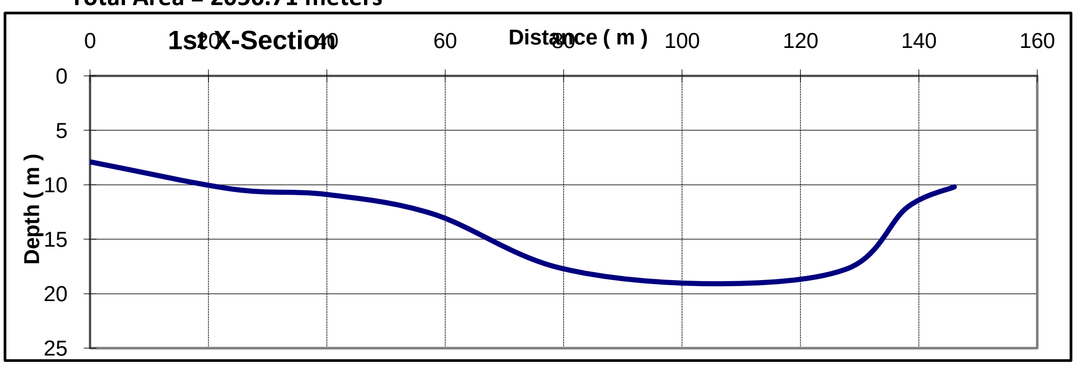

Figure 11. Slope-area method cross section 1

Total Area = 1525.85 meters^2

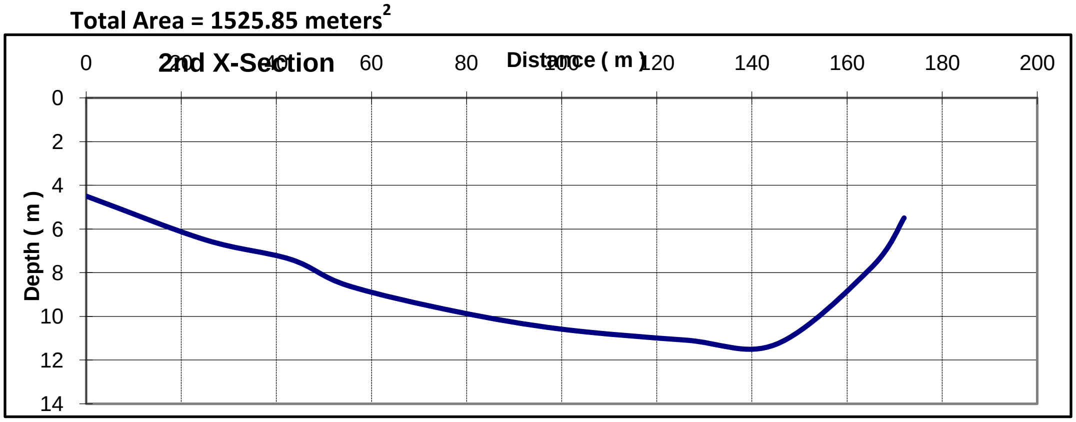

Figure 12. Slope-area method cross section 2

Total Area = 1676.52 meters^2

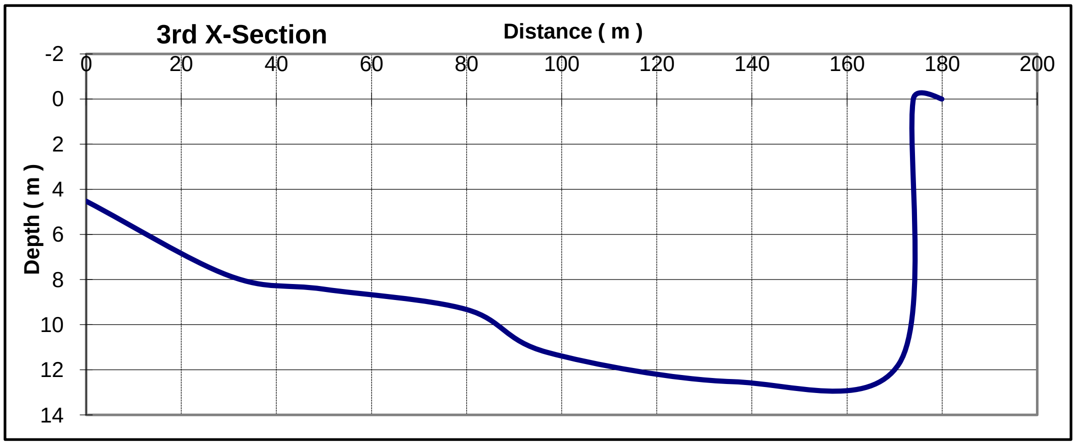

Figure 13. Slope-area method cross section 3

The slope of the river which was obtained by taking the difference of the highest water elevations from the first and the last cross sections divided by the total reach. A slope value of 0.00015 was then computed. The roughness coefficient used was 0.030. Substituting these values together with other parameters computed in the Manning's formula, a discharge of 2,389.70 was obtained for this method.

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**

A total of eight transects was measured by the group using the Acoustic Doppler Current Profiler (ADCP) which is summarized in the table above. An average of 288.881 cu.m per second was then computed. A sample of the transects is shown in the succeeding figure.

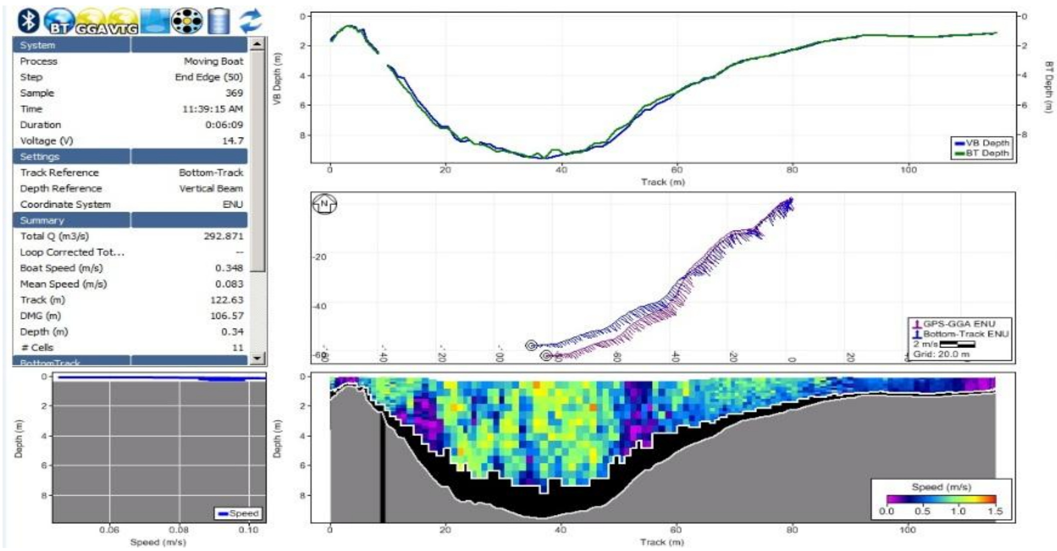

Figure 14. ADCP transects

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

As for the current meter method, velocity was measured at 0.6 of the water depth and beeps were recorded within a minute. Out of the 20 verticals, a few were not able to measure velocity due to decreasing water depth from the left bank to the right bank. Another factor which has made measurement impossible is that the flow of the water is controlled by the closing of the Cong Dadong Dam upstream. Water level also decreased since Day 1 of the fieldwork measurements. Several notes in the table above can be found such that entries for the no. of beeps = "unable" which accounts for the negligible flow of water although the current meter can still measure and no. of beeps = "NA" wherein water depth is too shallow or the river bed is already exposed which make it impossible to make measurements.

Table 5: Summary of Discharge Measurements done by each group

Method	Float	Slope-Area	ADCP	Current Meter
Day 1	**738.24**	3, 983.73	466.911	311.48
Day 2	614.02	**2, 389.70**	441.287	325.7
Day 3	493.163	3, 440.34	**288.881**	293.42
Day 4	240.62	3, 579.19	237.668	**13.86**

Results from the different methods for the four-day actual fieldwork reveal a decreasing pattern from Day 1 to Day 4. Discharge is practically high on the first day for all of the methods while a few deviations were also seen. All the measurements taken were implemented and analyzed presenting some problems in the final computations. Although the values computed vary, it is important to note that the correct process was understood and measurements can be improve in the future if similar task will be done. Aside from the four methods of discharge measurement, an additional cross section taken from the bridge was also taken and used in the determination of the rating curve and rating table for Arayat. At different gauge heights, discharges were computed and plotted to come up with the rating curve. Similarly, a graph of the gauge height and area was also derived.

Pampanga River @ Arayat							
(based on cross-section undertaken on October, 2013)							
Elevation of "0" of S.G.=		0.082	m.(AMSL)				
n=	0.030	I=	0.00015				
Elevation	Equivalent	Area	Width	W.P.	hyd radius	Discharge	Remarks
MSL (m)	G.H.(m)	a (m^2)	w (m)	s	r	Q (cumecs)	
15.40	15.320	3363.89	292.34	302.21	11.13	6846.29	
15.00	14.918	3247.38	291.50	300.97	10.79	6473.36	
14.00	13.918	2956.91	288.60	297.38	9.94	5581.85	
13.00	12.918	2670.61	286.30	294.09	9.08	4745.56	
12.00	11.918	2385.26	283.15	290.25	8.22	3965.54	
11.00	10.918	2104.14	281.00	287.13	7.33	3240.86	
10.00	9.918	1824.65	278.00	283.48	6.44	2577.59	
9.00	8.918	1548.21	275.30	279.97	5.53	1976.52	
8.00	7.918	1291.18	236.10	240.54	5.37	1616.03	
7.00	6.918	1053.37	162.40	166.46	6.33	1471.25	
6.00	5.918	902.84	137.90	141.81	6.37	1266.12	
5.00	4.918	769.53	128.20	131.89	5.83	1018.18	
4.00	3.918	643.90	122.10	125.45	5.13	782.18	
3.00	2.918	525.10	116.30	119.21	4.40	576.02	
2.00	1.918	412.62	108.00	110.58	3.73	405.26	
1.00	0.918	310.25	98.00	100.34	3.09	268.82	
0.50	0.418	262.09	93.50	95.73	2.74	209.40	
-1.00	-1.082	163.04	56.40	57.80	2.82	132.88	
-2.00	-2.082	110.61	40.90	42.35	2.61	85.63	
-3.00	-3.082	72.23	36.90	37.84	1.91	45.37	
-4.00	-4.082	39.10	30.70	31.30	1.25	18.51	
-5.00	-5.082	11.85	25.00	25.27	0.47	2.92	

Figure 15: Discharge vs. Height table

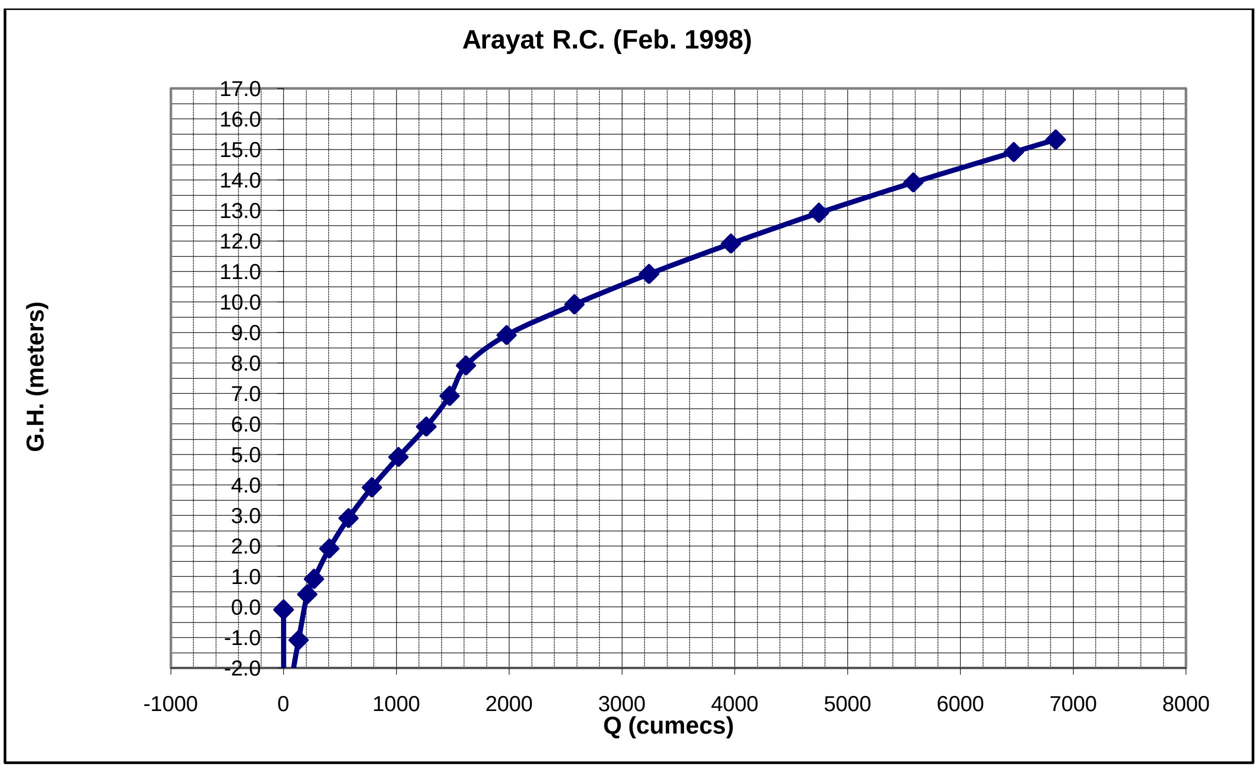

Figure 16: Rating curve at Arayat station

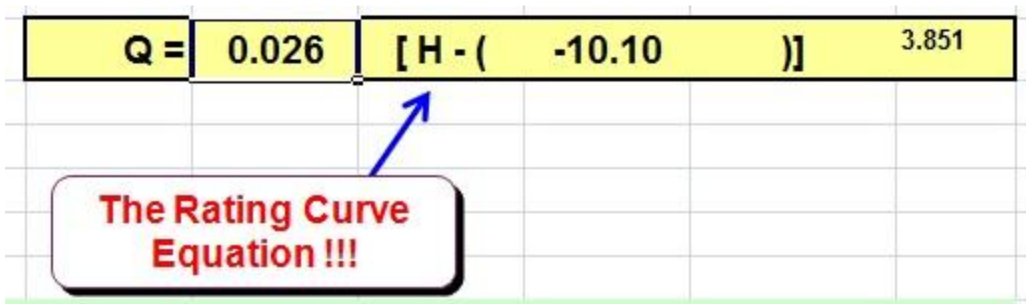

Figure 17: Rating Equation

7. 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. Proper practice and understanding on the mechanism used in this method will make data gathering and computations easy in the long run.

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.

Current-meter is the most commonly used method by the USGS for measuring discharge. A more reliable result should have been arrived at if the limitations and the quality of the instrument and the presence of dam upstream were addressed.

Finally, the derivation of a rating curve is a good way to see the relationship between water level (stage) and the corresponding discharge of the river. It is the best input as boundary conditions for flood modelling.

8. Future Developments

This fieldwork activity is a practical application of the four discharge measurement techniques. 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.

9. Travel Insights

La Mesa Watershed was the first stop and the first of the dams visited during the field work. La Mesa dam and reservoir stores water for use during the dry months and is primarily a sedimentation basin. It houses the filtration plant that distributes water to 5 cities and 32 municipalities or about 12 million residents in Metro Manila. It is also the last forest of its size in the metropolis.

It's day 5 when we visited Pantabangan Dam in Nueva Ecija. It's a four hours trip from Pampanga. The visit was then welcoming as the staff was waiting for our arrival and prepared snacks for us. They welcomed us with lectures regarding their area of responsibility and toured us on the vicinity. The flood forecasting and warning center has a mix of modern and a bit of old school facilities. The dam's watershed turned out to be a breathtaking landscape, it's a man made reservoir and one of the largest in Asia.

A week after when we went to Cong Dadong Dam just within the vicinity of Arayat, Pampanga. The Cong Dadong Dam is a diversion dam that its main purpose is for irrigation year-round of the farm lands in Pampanga. It's named after President Diosdado Macapagal.

At day 9 we went to Calumpit in Bulacan and visited the Municipal Disaster Risk Reduction and Management Council (MDRRMC). The town claims to be a flood-loving municipality. They are easily affected when the Pampanga River rise at a certain level. The LGU do flood forecasting or flood monitoring in their town using an Excel Suite. Next stop is the Sunken Church in Bacolor, Pampanga the San Guillermo Parish Church. It was half-buried with lahar caused by the eruption of Mt. Pinatubo in 1991. For now, it is still preserved and is one of the tourist spots in Pampanga. Last stop was in Angeles City in Pampanga.

Before going back to Manila at the last day of the trip we dropped by at Angat Dam in Norzagaray, Bulacan. It supplies Metro Manila to about 97 percent of clean water. We're given a closer look at the facilities below the Hydroelectric Power Plant. We've seen huge generators, large rotors and armatures and substation.

10. 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.

11. References

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