Republic of the Philippines
Philippine Atmospheric, Geophysical and Astronomical Services Administration
Hydrologists Training Course 2013-2014

TECHNICAL REPORT IN

DISCHARGE MEASUREMENTS USING VARIOUS METHODS AND SITE VISITS

PAMPANGA RIVER, BRGY CAMBA, ARAYAT, PAMPANGA

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I INTRODUCTION

The discharge of a river is defined as the volume of water flowing past a particular point in unit time. The Philippine Atmospheric, Geophysical and Astronomical Services Administration is collecting discharge measurements of the major rivers in the country to develop and verify ratings for water level gauges, to analyse hydraulic structures, and to calibrate hydraulic models. Discharge data are also used operationally in navigation, hydropower production, lake regulation, water level forecasting, water apportionment, monitoring of compliance with agreements and treaties and in a wide range of studies.

Various methods of discharge measurements are established in the field of hydrology. During the field work period, 3 direct methods and 2 indirect methods are used. This methods have different results but significantly precise from one another. As expected each method has its pros-and-cons and ac curacy is dependent on the selected gaging stations and the type of flow. Direct methods shall be done at high flows ideally after a storm or which flooding occurs. Indirect means of discharge measurements doesn’t require high flows or flood events. The accuracy of the method is largely dependent on the acquired data of the measurable parameters on the actual gaging site.

II OBJECTIVES

The rating curve of a certain river describes it stage-discharge relationship. This is the purpose among hydrologists measuring all needed parameters in the gaging station. In hydrology, a rating curve is a graph of discharge versus stage for a given point on a stream, usually at gauging stations, where the stream discharge is measured across the stream channel with a flow meter. Numerous measurements of stream discharge are made over a range of stream stages. The rating curve is usually plotted as stage on x-axis versus discharge on y-axis.

These models are great tools in predicting floods and to warn people of incoming calamity. By models, floods can be mitigated. Simulation tools will reveal flood prone areas and give agency the bigger picture and the idea of the actions that should be undertaken to avoid damage to properties or even death. Flood mitigation involves the managing and control of flood water movement , such as redirecting flood run-off through the use of floodwalls and flood gates, rather than trying to prevent floods altogether. It also involves the management of people, through measures such as evacuation and dry/wet proofing properties for example. The prevention and mitigation of flooding can be studied on a number of levels: individual properties, small communities and whole towns or cities. The costs of protection rise as more people and property are protected.

III SITE DESCRIPTION

San Agustin Bridge, Brgy. Camba, Arayat, Pampanga

Pampanga River from downstream of Mount Arayat

The chosen gaging site is the Pampanga River stretching below San Agustin Bridge in Barangay Camba, Arayat, Pampanga. Pampanga River (formerly known as *Rio Grande de Pampanga* - Great River of Pampanga) 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.

The river's basin covers an area of 10,540 km², including the allied basin of Guagua River. The basin is drained through the Pampanga River and via the Labangan Channel into the Manila Bay.

Its main tributaries are Peñaranda and the Coronel-Santor Rivers on the eastern side of the basin and the Rio Chico River from the northwest side. The Angat River joins the Pampanga River at Calumpit, Bulacan via the Bagbag River. Mount Arayat (elevation: 1,026) stands in the middle of the basin. Southeast of

Mount Arayat and the Pampanga River is the Candaba Swamp, covering an area of some 250 km². absorbing most of the flood flows from the western slopes of a portion of the Sierra Madre and the overflowing of the Pampanga River via the Cabiao Floodway. This area is submerged during the rainy season but is relatively dry during summer.

The field works were done on the 17th, 18th, 21st and 22nd of October 2013 were the following methods: Current Meter Method, Float Method, Slope-Area Method and the use of Acoustic Doppler Current Meter (ADCP) were done respectively on each day. The type of weather is generally sunny .The stage of the river in the first day of the field work was high as typhoon Santi hit a few days ago in the area but gradually receding as the days progressed.

The current meter and the float method were done on top of the San Agustin Bridge with about 300 linear meters in length. The river width from left-water-edge to right-water-edge directly below the bridge during the field works is observed to be 120-160 meters depending on the receding stages of the water. The type of soil is clay and sandy. It was very soft on the first day and ponding is observed in many areas along the banks. The right bank downstream from the bridge is an agricultural land .The left bank has been left uncultivated with scattered trees growing in the vicinity. Further downstream, grasses and agricultural crops are observed along the plain.

Right Bank of Pampanga River

Clay and Sandy Soil along the banks.

IV METHODOLOGY

CURRENT METER METHOD - Day 1 (October 17, 2013)

Equipment Used:

Price AA Current Meter Set (v=0.072N+0.013)
This includes the Columbus weights, Sounding Reel with Depth Indicator, and Beeper
Timer,
Notebook and Pencil (Data encoding)

Method:

. The length of the bridge atop the river section is measured and marked as to indicate station points starting from the left bank where the water edge was directly below. The station interval was agreed to be at every five (5) meters. Current meter parts were assembled by coupling the meter and the Columbus weight thru a hanger bar and attached to the cable from the reel, and connecting depth indicator and the current meter timer which counts every revolution of the rotor made during a specified time interval. Starting from the first established point on the left bank side, the equipment was placed and set the computing depth indicator to zero. The current meter was brought down thru a cable until it reaches the water surface. At this time the height of the bridge to the water surface was recorded. From the water surface the current meter was lowered until it reached the river bed. Knowing now the depth of the river on that specific column, the revolutions of the current meter was counted and recorded at the depth of 0.2, 0.6 and 0.8 of the total depth from the water surface. These were done actually by counting the beep (which was set to 1 beep per 5 revolutions) within 60 seconds after the device was stabilized on that point in the water.

These steps were repeated on every 5-meter interval until at the last established point on the bridge. See figure below.

The mean velocity is then computed based on the 3-point method, ,2-point method or 1-point method depending on the depth of the section..

Advantage of Current Meter Method:

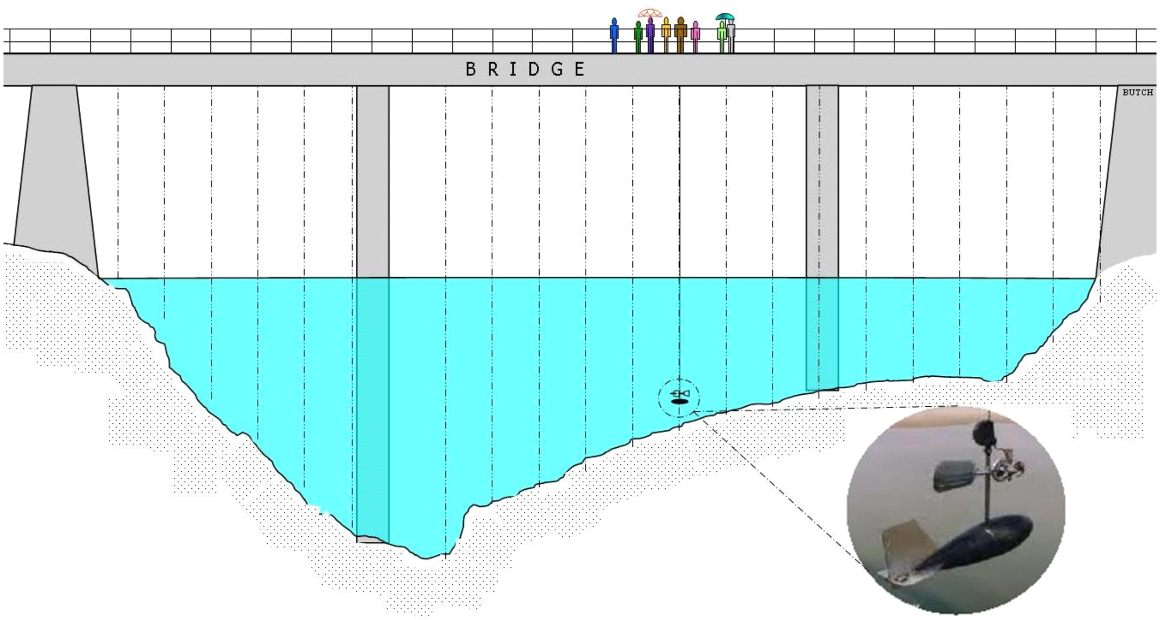
• Reliable when there is no significant floating objects flowing on the stream that tends to distort or obstruct the revolutions of the bucket wheel.

• Suitable on depth greater than 2.5 feet.

Disadvantage of Current Meter Method:

• If there are numerous floating objects like water lilies or algae along the river that obstruct the rotation of the bucket wheel.

• If the current of the river is very slow that it will not make the bucket to rotate.



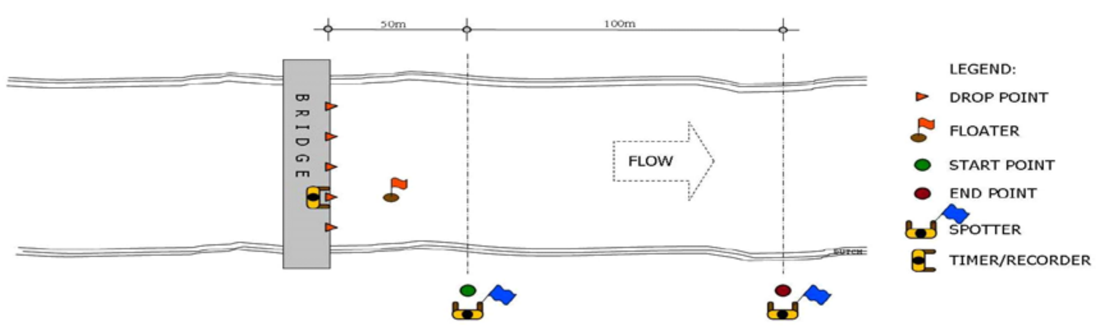
FLOAT METHOD - **Day 2 (October 18, 2013)**

Equipment Used:

- tape measure
- stop-watch
- sounder to measure water depth
- 10 pcs x 0.5m bamboo as visible buoyant objects
- stakes for anchoring tape measure to stream banks
- notebook for recording purposes

Method:

A portion of the river that has fairly straight course was selected. Directly downstream from the bridge was a good spot based on the judgement of the group. Starting point was about 50 meters from the bridge and the end point was 100 meters downstream from the starting point. Five (5) drop-off points are established and marked on the bridge. The bamboo floats are dropped on the bridge and the timer is started as soon as it passed the starting point and was stopped as soon as it reached the end point. This data of distance and time was used to determine the velocity of the current.



The river's cross section was obtained by means of echo sounding device. It was done by riding a boat while crossing the river. Depth of the river bed was recorded at every few meters along the river from the left bank to the right bank. The recorded depths determines the depth of the river which eventually to be used in the discharge measurement in this specific method.

Advantages:

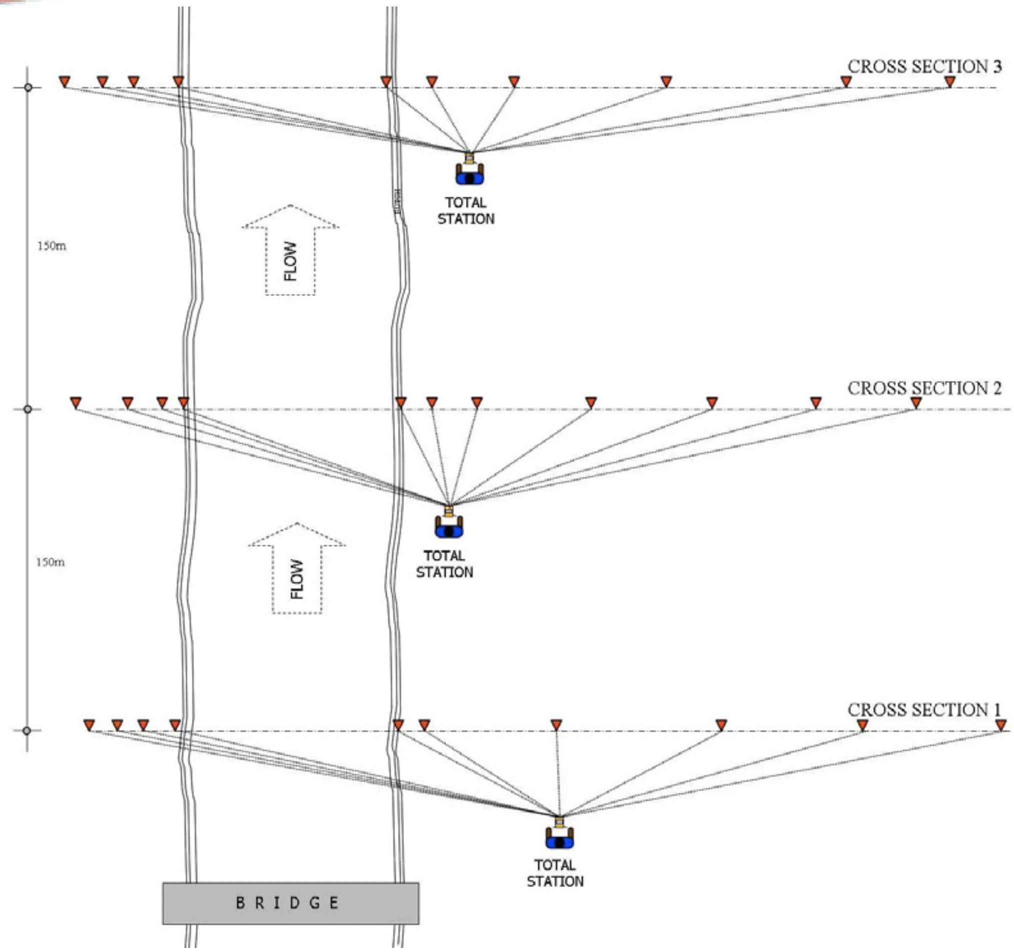
- Simple and inexpensive.
- No required special equipment or expertise.

Disadvantages:

- Not applicable in a very low flow.
- The need of a fairly straight course/run of the river.
- The need of not less than 3 person to perform the method.

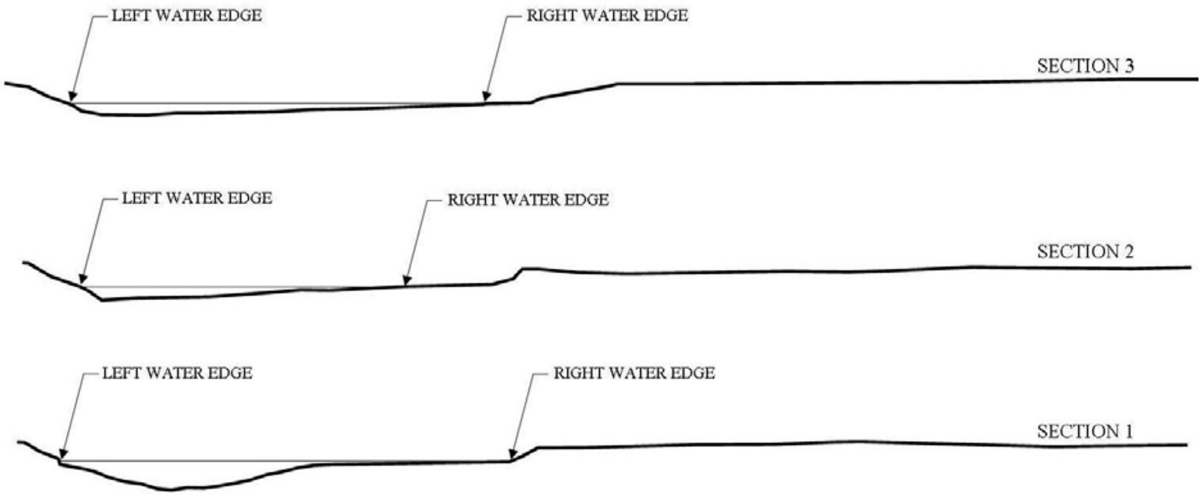
SLOPE-AREA METHOD - Day 3 (October 21, 2013)

The area 50 m downstream of the bridge was divided into three cross section 150 meters apart. In section 1, points were established from the flood mark to the right bank and from the left bank to the flood mark (on the other side of the river). In each point, elevation and distance were determined using the Total Station. These steps was repeated in sections 2 & 3. Refer to illustration on the next page.



The river's cross section was obtained by means of echo sounding device. It was done by riding a boat while crossing the river. Depth of the river bed was recorded at every few meters along the river from the left bank to the right bank. The recorded depths determines the depth of the river which eventually to be used in the discharge measurement in this specific method.

The figure below represents the profile of each section on the river.



Advantages:

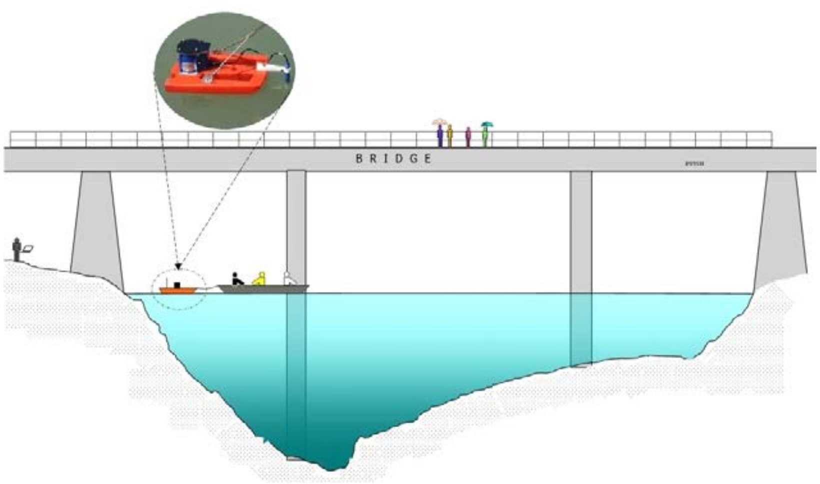
- It can determine the extent of discharge up to the flooding plain.
- It can trace the terrain from the flood plain to the water edge.

Disadvantages:

- Not applicable when flooding is eminent.
- The need of flood marks on the vicinity of the river.
- Very tedious to perform and the calculations are complicated.
- This method requires surveying skills.

Acoustic Doppler Current Profiler Method - **Day 4 (October 22, 2013)**

The ADCP brought along the river bank just a few meters from the old water level station. The instrument was carefully assembled by mounting the sensors on its floatation bay. By the use of the lap-top computer the ADCP was calibrated on its pitch, roll and yaw axes. After the calibration was done the ADCP was positioned approximately 50 meters upstream of the bridge and was towed by a boat across the river thrice for data acquisition. The instrument was used to measure how fast water is moving across an entire water column, measure current speed not just at the bottom, but also at equal intervals all the way up to the surface, measure the current profile from bank to bank. See figure below.



Advantages:

- In the past, measuring the current depth profile required the use of long strings of current meters. This is no longer needed.

- 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.
- Measures a water column up to 1000m long.
- At this apparatus, the so-called "human factor", as a source of errors, is eliminated.

Disadvantages:

- High frequency "pulse of sound" yield more precise data, but low frequency pulse of sounds 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.
- ADCPs set to "pulse of sound" rapidly also run out of batteries rapidly.
- If the water is very clear, as in the tropics, the pulse of sound may not hit enough particles to produce reliable data.
- Bubbles in turbulent water or schools of swimming marine life can cause the instrument to miscalculate the current.
- Users must take precautions to keep barnacles and algae from growing on the transducers.
- The apparatus is very expensive.

V RESULTS AND DISCUSSION

A. Current Meter Method

The acquired data for current meter method includes the discharge (Q) table and a graph of depth versus distance that represents the river cross-section below San Agustin Bridge.

Discharge Measurement (Current Meter) for :	*Arayat Station*	River:	*Pampanga*			PRFFC
DM #:		Date: October 17,2013	Team:	Group 1		FFB
Gage Height:	Start: 5.40	End: 5.28	Inst. # :	Wx:	fair	PAGASA
Observation Time:	Start: 1:35	End: 4:25	Calibration Eqtn.: V = 0.732	N+ 0.013	note: just input negative value	hth/97
	Vertical dist. to water surface (m) = 10.50				for latter if eqtn. is minus.	
Total Area (m^2) =	873.66	Ave. Gage Height =	5.34	Sectional Width (m) =		115.0
Total Q (m^3/s) =	311.48	Ave. Vel. (m/s) =	0.357			

Dist. from Initial point	Width (mts.)	Depth (ep for pier) (mts.)	Vert. Angle 4^0-36^0	Angle Corrected Depth	Observation Depth 0.2 Rev.	0.2 Time	0.6 Rev.	0.6 Time	0.8 Rev.	0.8 Time	Velocity at point for 0.6 only	Mean (0.2,0.6 & 0.8) or (0.2 & 0.8)	Area (m^2)	Q (cumecs)	Remarks Excellent, Good Fair, Poor
0				0											
5	5	3.05	0	range out			80	61.2			0.970	x	x	x	
10	5	5.35		5.350	95	63	85	60	85	61	1.050	1.062	26.75	28.42	
15	5	5.08		5.080	95	61	95	60	100	61	1.172	1.178	25.40	29.91	
20	5	8.31		8.310	110	61	35	65	35	69	0.407	0.633	41.55	26.30	
25	7.5	21.63		21.630							x	x	162.23	x	
35	7.5	21.57		11.170							x	x	83.78	x	
40	5	21.94		14.550							x	x	72.75	x	
45	5	22.48		22.480							x	x	112.40	x	
50	5	9.15	17	8.526	75	60	70	61	65	60	0.853	0.860	42.63	36.66	
55	5	8.02	8	7.891	90	62	85	62	75	63	1.017	0.998	39.46	39.39	
60	5	5.8		5.800	90	61	80	60	75	62	0.989	0.992	29.00	28.78	
65	5	5.77	5	5.724	95	62	85	65	70	62	0.970	0.979	28.62	28.01	
70	5	5.7		5.700	95	63	85	63	70	62	1.001	0.989	28.50	28.20	
75	5	5.28		5.280	85	61	80	61	70	62	0.973	0.955	26.40	25.20	
80	5	4.95		4.950							x	x	24.75	x	
85	5	5.1		5.100							x	x	25.50	x	
90	5	4.9		4.900							x	x	24.50	x	
95	5	4.65		4.650							x	x	23.25	x	
100	5	4.57		4.570	80	60	70	62	70	62	0.839	0.877	22.85	20.04	
105	5	3.39		3.390	60	60	60	60	60	63	0.745	0.736	16.95	12.48	
110	5	3.28		3.280	40	68			45	62	x	0.494	16.40	8.10	

Rem:	Total Area =	873.66
	Total Discharge =	311.48
	Ave. Velocity =	0.357

Table 1. **Discharge (Q) Table using Current Meter Method**

Table 1 above made use of Microsoft Excel Suite that obtains an equivalent total discharge simply by completing all the following beige cells:

- Name of station and name of river
- Gage height at the beginning and end of the activity
- Calibration equation (general formula)
- Vertical distance to water surface in meters
- Distances from the initial point in meters
- Depths of each distance in meters
- Vertical angles ranging only from 4 to 36 degrees (otherwise, leave it blank)
- The number of revolutions within not less than 60 seconds, depending on the depth points used. For shallow points, only the 0.6 depth was filled. For deeper points, all the observation depths 0.2, 0.6, and 0.8 were filled up.
- Remarks or rating of the observation (optional)

Observe from Table 1 that not all sections have a recorded observation depth. This may be due to piers, water lilies, and turbulent flows that hindered in getting an accurate number of revolutions at a certain time. Next, filling up the beige cells will reveal the following data in white cells:

- ✓ Width of each subsection in meters
- ✓ A corrected vertical angle
- ✓ Computed velocity at one-point depths and mean velocity for three-point depths
- ✓ Area of each subsection in square meters
- ✓ Discharge of each subsection in cubic meters per second or cumecs
- ✓ Total area of the cross-section or simply the sum of all the subsections
- ✓ Total discharge of the cross-section or the sum of all the discharges
- ✓ Average of the computed and mean velocities

The recorded discharge from the Acoustic Doppler Current Profiler (ADCP) that day was around 250 to 280 cumecs. Arriving at 311.48-cumec discharge, which is way larger compared to the expected value, may be due to insufficient data along the piers and other obstructions below a subsection.

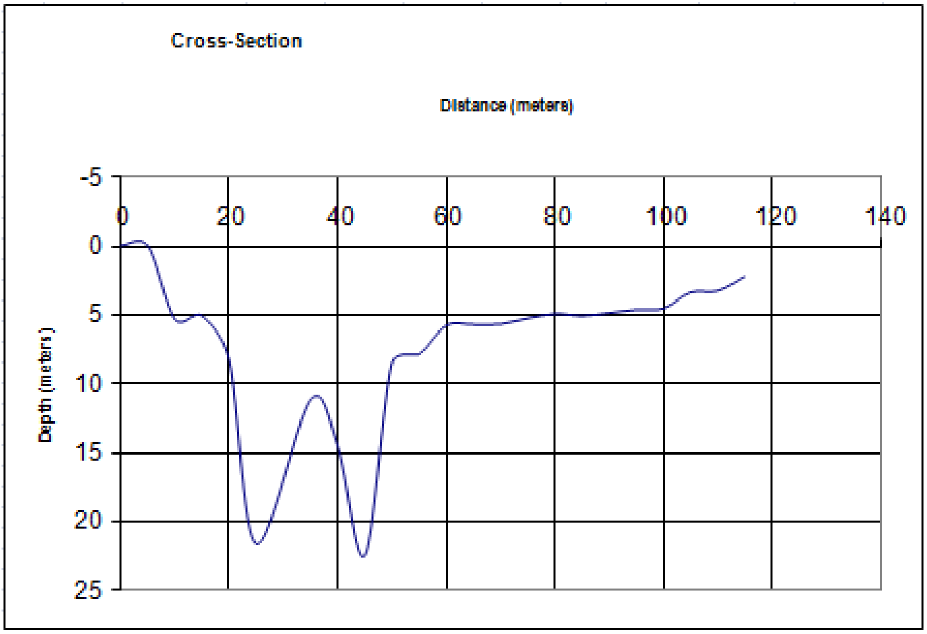


***Figure 1*. Pampanga River Cross-section Derived from Distance-Depth Relation**

Figure 1 reveals the cross-section of Pampanga River below San Agustin Bridge using the distance and depth acquired from the Q table. The curve shows how the cross-section has its deepest points near the left water edge and shallower on the right half of the river.

B. Float Method

The acquired data for float method includes two manually computed tables for the physical parameters of each cross-section, their cross-sections based on distance versus elevation, and the equivalent discharge table for the two transects.

station	distance	elevation	water sfc.	depth	mean depth	area	wetted perimeter
0.00		4.73	4.73	0.00			
24.00	24.00	2.33	4.73	2.40	1.20	28.80	24.12
39.00	15.00	1.93	4.73	2.80	2.60	39.00	15.01
40.00	1.00	1.73	4.73	3.00	2.90	2.90	1.02
58.00	18.00	-0.07	4.73	4.80	3.90	70.20	18.09
79.00	21.00	-4.97	4.73	9.70	7.25	152.25	21.56
91.00	12.00	-5.57	4.73	10.30	10.00	120.00	12.01
105.00	14.00	-6.47	4.73	11.20	10.75	150.50	14.03
110.00	5.00	-6.67	4.73	11.40	11.30	56.50	5.00
128.00	18.00	-5.07	4.73	9.80	10.60	190.78	18.07
142.00	14.00	-3.47	4.73	8.20	9.00	125.97	14.09
146.00	4.00	2.43	4.73	2.30	5.25	20.99	7.13
149.00	3.00	4.73	4.73	0	4.73	x	x
Total Width	**149**						
Total Area	**957.896**						
W. P (P)	**150.1368**						
Hydraulic Radius ®	**6.380154**						
Mean sect. Depth	**6.428832**						

***Table 2a*. Physical Parameters for the First Cross-section using Float Method**

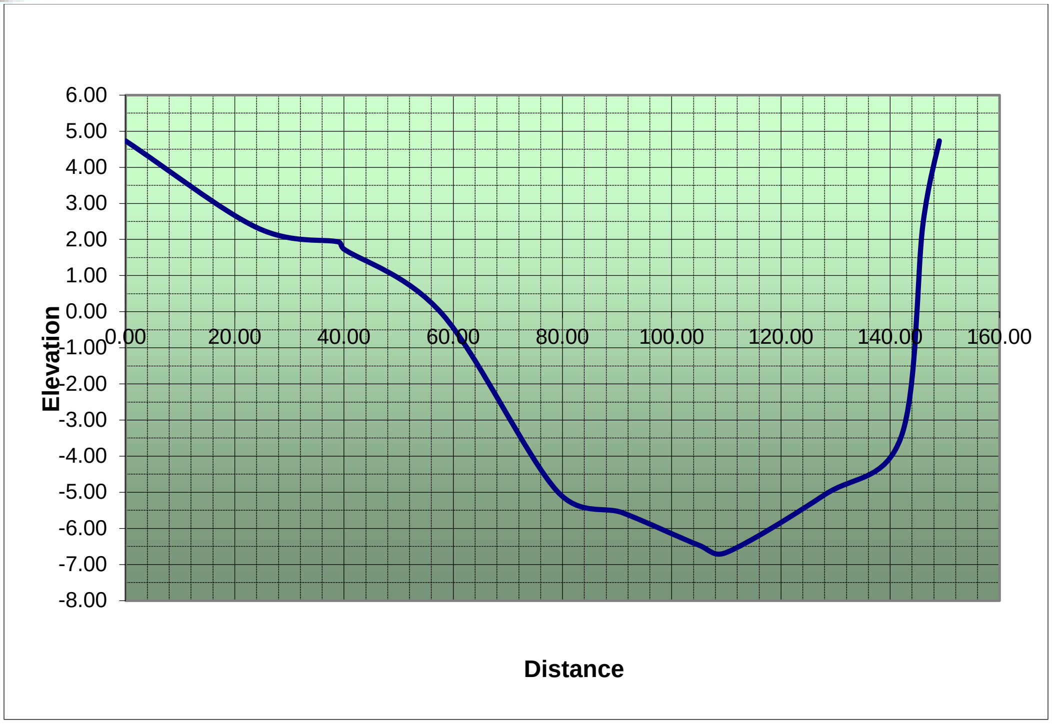


Figure 2a. **Equivalent First Cross-section using Distance and Elevation**

station	distance	elevation	water sfc.	depth	mean depth	area	wetted perimeter
0.00		4.73	4.73	0.00			
25.00	25.00	2.73	4.73	2.00	1.00	25.00	25.08
43.00	18.00	1.83	4.73	2.90	2.45	44.10	18.02
47.00	4.00	1.83	4.73	2.90	2.90	11.60	4.00
55.00	8.00	0.63	4.73	4.10	3.50	28.00	8.09
65.00	10.00	0.23	4.73	4.50	4.30	43.00	10.01
78.00	13.00	-0.57	4.73	5.30	4.90	63.70	13.02
84.00	6.00	-0.77	4.73	5.50	5.40	32.40	6.00
100.00	16.00	-1.37	4.73	6.10	5.80	92.80	16.01
105.00	5.00	-1.57	4.73	6.30	6.20	31.00	5.00
118.00	13.00	-2.07	4.73	6.80	6.55	85.12	13.01
126.00	8.00	-1.87	4.73	6.60	6.70	53.58	8.00
138.00	12.00	-1.57	4.73	6.30	6.45	77.38	12.00
145.00	7.00	-2.07	4.73	6.80	6.55	45.84	7.02
165.00	20.00	1.43	4.73	3.30	5.05	100.96	20.30
172.00	7.00	3.73	4.73	1.00	2.15	15.04	7.37
174.00	2.00	4.73	4.73	0	4.73	x	x
Total Width	**174**						
Total Area	**749.511**						
W. P (P)	**172.9488**						
Hydraulic Radius ®	**4.333715**						
Mean sect. Depth	**4.307534**						

Table 2b**. Physical Parameters for the Second Cross-section using Float Method**

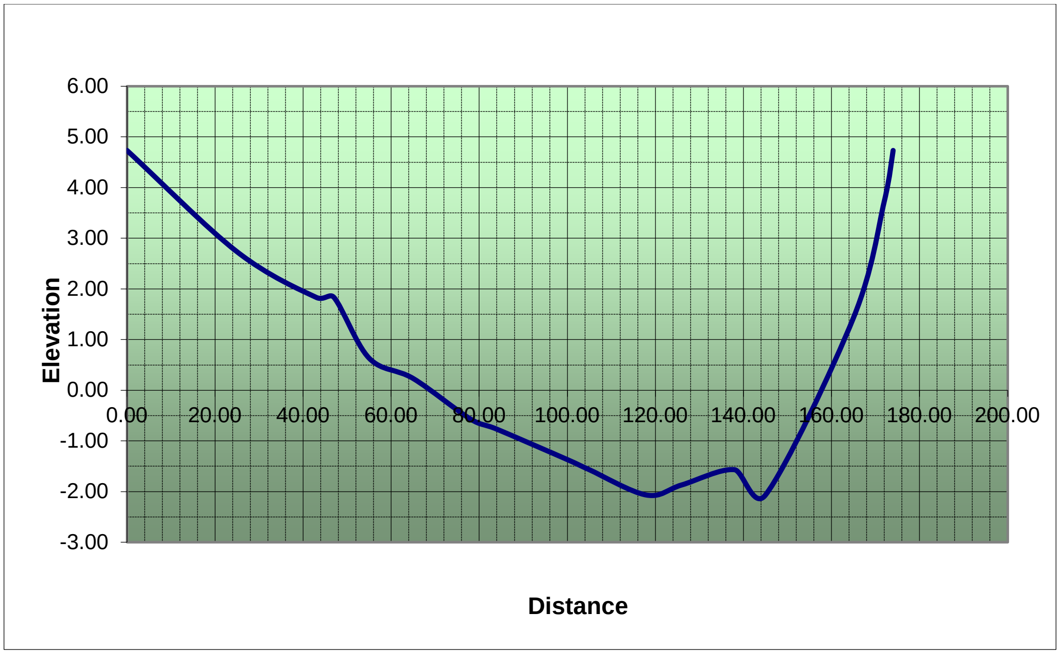


Figure 2b. **Equivalent Second Cross-section using Distance and Elevation**

Station	Traveling time		Ave Time (sec)	Velocity (m/s)	Correction Coeff	Corrected Vel (m/s)	1st Section (m^2)	2nd Section (m^2)	ave Area (m^2)	Divided Q (m^3/s)
	1st trial	2nd trial								
1	FAIL	1:36:59	96.00	1.04	0.92	0.959	54.71	62.35	58.53	56.11
2	01:37:37	1:51:30	104.00	0.96	0.92	0.885	107.50	143.50	125.50	111.01
3	1:34:11	FAIL	93.00	1.08	0.92	0.989	197.50	125.40	161.45	159.72
4	1:37:35	1:38:36	97.50	1.03	0.92	0.944	262.50	165.10	213.80	201.74
5	2:17:50	2:12:27	134.55	0.74	0.92	0.684	91.43	158.40	124.91	85.44
								Total Discharge= 614.02m^3/s		

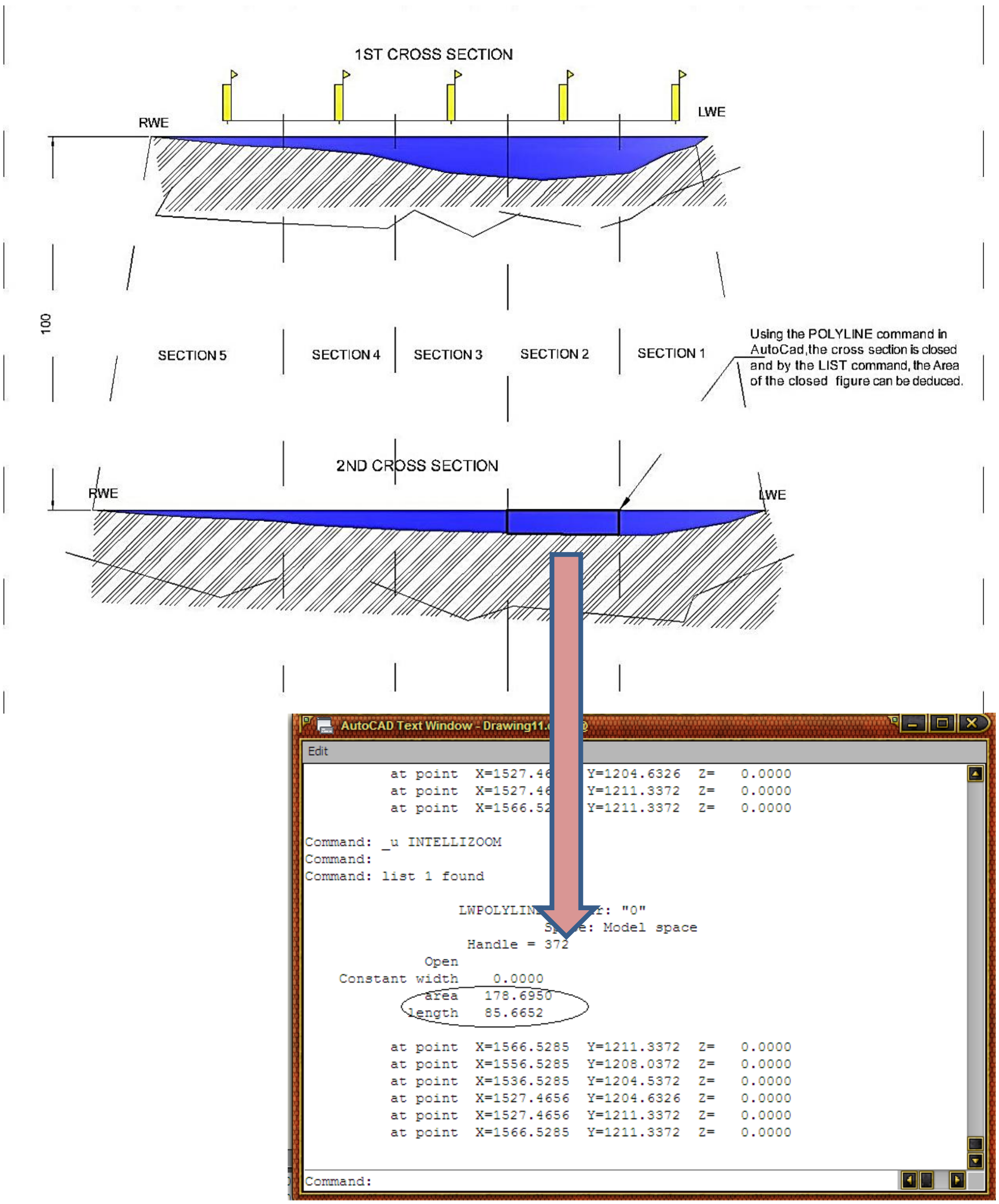
Table 2c. **Discharge (Q) Table for the Two River Cross-sections using Float Method**

The velocity of the float is computed using the 100 horizontal distance from the two assigned points along the river divided by the travel timed elapsed as the current carry the float passing thru the points.

The average velocities of the float are used since it has two trials. Floats unable to ascend to the water surface upon dropping are labelled FAIL in the table.

The cross section of the river bed is computed using the Autodesk AutoCad version 2010. By the POLYLINE command, the cross sections are encoded into the program. Each closed boundary (polygon) is then selected and the LIST command is executed. Several information about the section is then flashed in the monitor.

The two cross sections have two different widths from edge to edge. To minimize errors, the average sectional area bounded by the imaginary line is used.



Utilizing AutoCad by Autodesk Corporation to compute the Cross Section of the River

Float method shows a similar, but simpler approach compared to the slope-area method. Microsoft Excel Suite may be used (Tables 2a and 2b) in determining the total width, area, wetted perimeter, hydraulic radius, mean depth, and a graphic representation of the cross-sections (Figures 2a and 2b).

However, the discharge (Q) table is the most important among the given data since it shows in detail the time it took for one float to travel from one cross-section to another. From this, the mean velocity of the two trials can be obtained. A FAIL on one trial shall be disregarded so the average time will be the other trial itself. Table 2c was manually computed, revealing a total average discharge of **614.02 cumecs**. This is roughly 7 to 8 times higher compared to the discharge measurement using current meter method.

C. Slope-Area Method

Data for the slope-area method includes three tables for the physical parameters of the three cross-sections, graphic representation of such parameters, and a summary table for determining the equivalent discharge of Pampanga River.

Cross-Section number ONE (1)							hth/97
Station	Distance	Elevation	Water Sfc. elev.	Depth	Mean Depth	Area	Wetted Perimeter
0		8.451	5.546	-2.905			
134.1687	134.1687	6.55	5.546	-1.004	-1.9545	-262.233	134.1822
143.8222	9.6535	3.997	5.546	1.549	0.2725	2.630579	9.985383
154.2193	10.3971	0.05	5.546	5.496	3.5225	36.62378	11.12108
167.8637	13.6444	0.006	5.546	5.54	5.518	75.2898	13.64447
185.8268	17.9631	-0.029	5.546	5.575	5.5575	99.82993	17.96313
206.3107	20.4839	-0.069	5.546	5.615	5.595	114.6074	20.48394
227.8004	21.4897	-0.099	5.546	5.645	5.63	120.987	21.48972
244.9382	17.1378	-0.149	5.546	5.695	5.67	97.17133	17.13787
271.3575	26.4193	-0.054	5.546	5.6	5.6475	149.203	26.41947
279.6424	8.2849	5.299	5.546	0.247	2.9235	24.22091	9.863781
284.2909	4.6485	5.546	5.546	0	0.1235	0.57409	4.655058

Total Width =	284.29	meters	Hydraulic Radius(r) =		1.60	meters
Total Area =	458.91	meters^2	Mean Section Depth =		1.61421	meters
Wetted Perimeter(P) =	286.946	meters				

***Table 3a*. Physical Parameters of the 1st Cross-section Using Slope-Area Method**

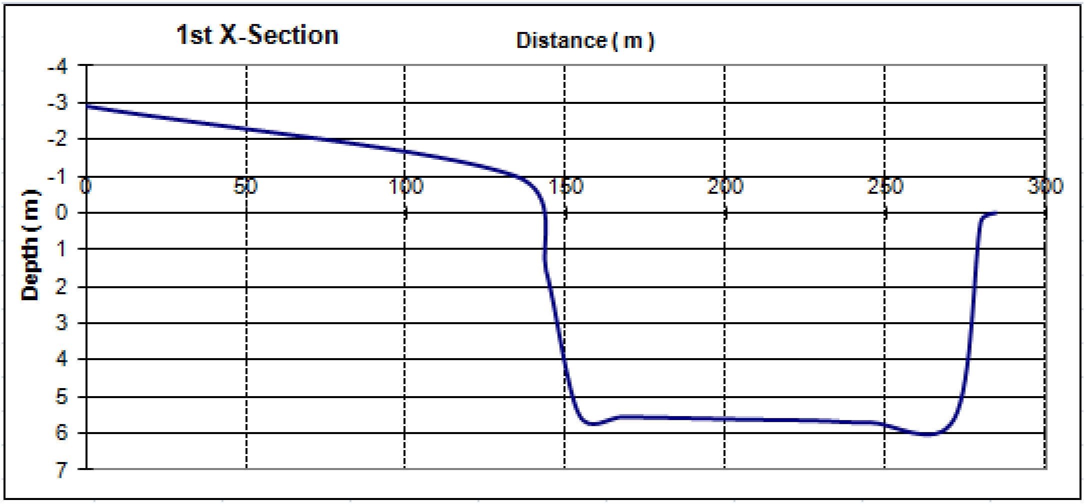


***Figure 3a*. Graphic Representation of the 1st Cross-section Using Distance-Depth Relation**

Cross-Section number TWO (2)							hth/97
Station	**Distance**	**Elevation**	**Water Sfc. elev.**	**Depth**	**Mean Depth**	**Area**	**Wetted Perimeter**
0		5.061	5.061	0			
166.1196	166.1196	4.018	5.061	1.043	0.5215	86.63137	166.1229
176.4954	10.3758	-0.003	5.061	5.064	3.0535	31.68251	11.1277
193.3365	16.8411	-0.029	5.061	5.09	5.077	85.50226	16.84112
209.3011	15.9646	-0.064	5.061	5.125	5.1075	81.53919	15.96464
227.7976	18.4965	-0.057	5.061	5.118	5.1215	94.72982	18.4965
247.5566	19.759	-0.103	5.061	5.164	5.141	101.581	19.75905
271.4966	23.94	-0.149	5.061	5.21	5.187	124.1768	23.94004
293.6271	22.1305	-0.179	5.061	5.24	5.225	115.6319	22.13052
314.3919	20.7648	-0.28	5.061	5.341	5.2905	109.8562	20.76505
321.6627	7.2708	4.653	5.061	0.408	2.8745	20.89991	8.786297
323.2061	1.5434	5.659	5.061	-0.598	-0.095	-0.14662	1.842314

Total Width =	**323.21**	**meters**	**Hydraulic Radius(r) =**	**2.62**	**meters**
Total Area =	**852.08**	**meters^2**	**Mean Section Depth =**	**2.63635**	**meters**
Wetted Perimeter(P) =	**325.776**	**meters**			

***Table 3b*. Physical Parameters of the 2nd Cross-section Using Slope-Area Method**

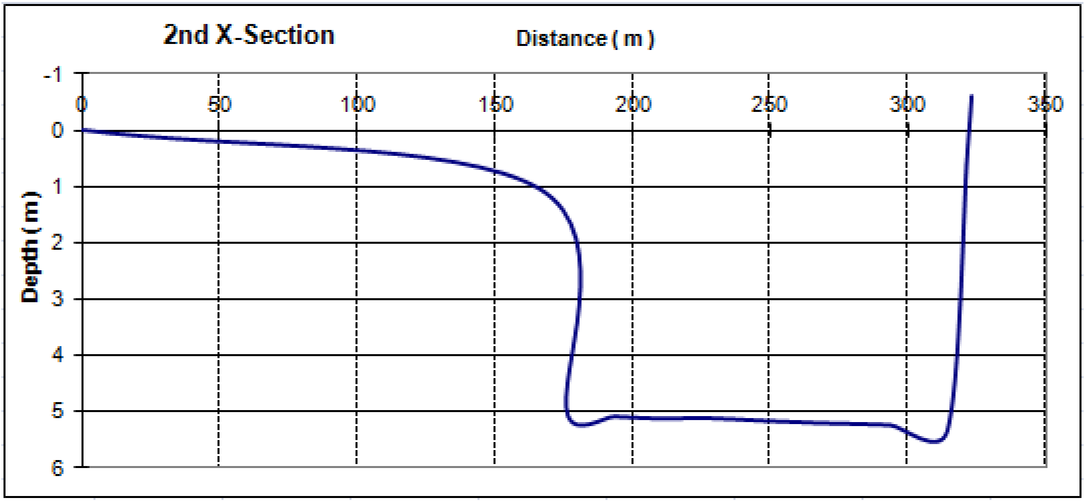


***Figure 3b*. Graphic Representation of the 2nd Cross-section Using Distance-Depth Relation**

Cross-Section number THREE (3)							hth/97
Station	**Distance**	**Elevation**	**Water Sfc. elev.**	**Depth**	**Mean Depth**	**Area**	**Wetted Perimeter**
0		4.967	4.967	0			
100.0491	100.0491	3.318	4.967	1.649	0.8245	82.49048	100.0627
125.3529	25.3038	-0.483	4.967	5.45	3.5495	89.81584	25.58769
138.9185	13.5656	-0.5	4.967	5.467	5.4585	74.04783	13.56561
155.9567	17.0382	-0.549	4.967	5.516	5.4915	93.56528	17.03827
178.0093	22.0526	-0.596	4.967	5.563	5.5395	122.1604	22.05265
201.759	23.7497	-0.671	4.967	5.638	5.6005	133.0102	23.74982
226.1464	24.3874	-0.715	4.967	5.682	5.66	138.0327	24.38744
248.0367	21.8903	-0.766	4.967	5.733	5.7075	124.9389	21.89036
265.2483	17.2116	-0.76	4.967	5.727	5.73	98.62247	17.2116
279.5832	14.3349	4.55	4.967	0.417	3.072	44.03681	15.28677
287.2792	7.696	4.793	4.967	0.174	0.2955	2.274168	7.699835

Total Width =	**287.28**	**meters**	**Hydraulic Radius(r) =**	**3.48**	**meters**
Total Area =	**1003.00**	**meters^2**	**Mean Section Depth =**	**3.49136**	**meters**
Wetted Perimeter(P) =	**288.533**	**meters**			

***Table 3c*. Physical Parameters of the 3rd Cross-section Using Slope-Area Method**

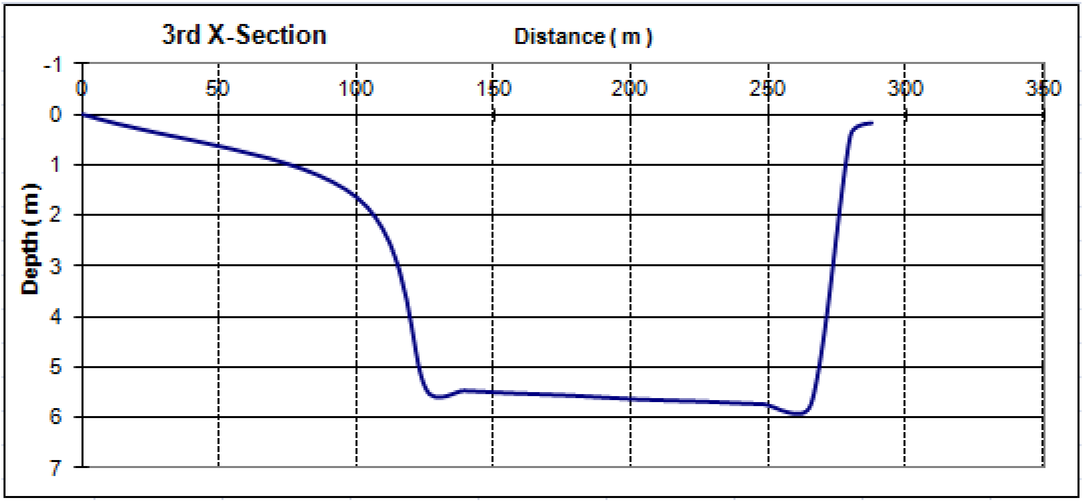


***Figure 3c*. Graphic Representation of the 3rd Cross-section Using Distance-Depth Relation**

Raw data for the slope-area method include horizontal distance from the total station, elevation or vertical distance, and water level for the three cross-sections. Inputting these to the Microsoft Excel Suite will automatically reveal the width, mean depth, area, and wetted perimeter (WP) of each subsection, as seen in Tables 3a, 3b, and 3c. The total width, area, WP, hydraulic radius, and mean section depth shall also appear at the bottom of these tables.

Other than the table, the raw data also shows on another sheet the graphic representation of the three cross-sections using the parameters of depth and distance. Comparing Figures 3a, 3b, and 3c, the cross-sections are somehow different from one another, though they reveal that the right bank has an abrupt rise in flood as compared to the left bank which has a wide flat plain proceeding to the highest flood mark.

FFB, PAGASA	Slope-Area Summary Sheet (3-Section)		
Station:	*Arayat Station*	River:	*Pampanga River*
Flood Date:		Drainage Area:	
Gauge Height:		Meas. #:	

X - Section Properties:

X-Sect.	Width	Area	Highwater Marks Left Bank	Highwater Marks Right Bank	Average Water Sfc.	d_m (mean depth)	n	r	K	K^3/A^2	α	F	State of Flow
1	284.29	458.91	8.451	5.546	6.9985	1.614	0.035	1.60	17959.04	2.8E+07	1	1.885	rapid
2	323.21	852.08	5.061	5.659	5.36	2.636	0.035	2.62	46364.11	1.4E+08	1	0.794	tranquil
3	287.28	1003.00	4.967	4.793	4.88	3.491	0.035	3.48	66034.39	2.9E+08	1	0.586	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	155.157	1.6385	0.5	expanding	0.387348	poor	655.495	4040.949	6.165
2-3	270.726	0.48	0.5	expanding	0.702121	good	927.540	2470.455	2.663
1-2-3	425.883	2.1185	0.5	expanding	0.271965	poor	771.328	3440.336	4.460

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	h_v D/S	Δh_v	h_f	$S=h_f/L$	$S^{1/2}$	K_w	Computed Q
1-2	4040.949	2.867476	0.831726	2.035749	2.656375	0.017121	0.130846	28855.76	3775.648
2-3	2470.455	0.831726	0.600272	0.231454	0.595727	0.0022	0.046909	55331.96	2595.582

$Q_{1\text{-}2\text{-}3}$ = 3440.34 cumecs

Discharge

Rem:

***Table 3d*. Slope-Area Summary Sheet of the Three Cross-sections**

The final table shows the slope-area summary sheet, where only the bank elevations, lengths of the reach, and a roughness coefficient *n* shall be inputted. The table is simply about the usage of Manning's formula and computation of discharge Q by multiplying the average area with the average velocity. Estimation of *n* is not easy, so it is assumed to be similar to a normal river which is 0.035. Based on calculations, the total discharge amounted to a whopping 3440.34 cumecs, almost 11 times higher than that of the current meter discharge.

D. ADCP Method

The *RiverSurveyor®* software illustrates in detail the river cross-section as well as its discharge in the shortest amount of time. This software program made by SonTek is Windows-based and operates in real time.

As mentioned, three trials were made across the same river cross-section, some 50 meters downstream from the bridge. A cross from one edge to the other edge is equivalent to one trial thus, one set of data. Captions were taken from the computer as follows:

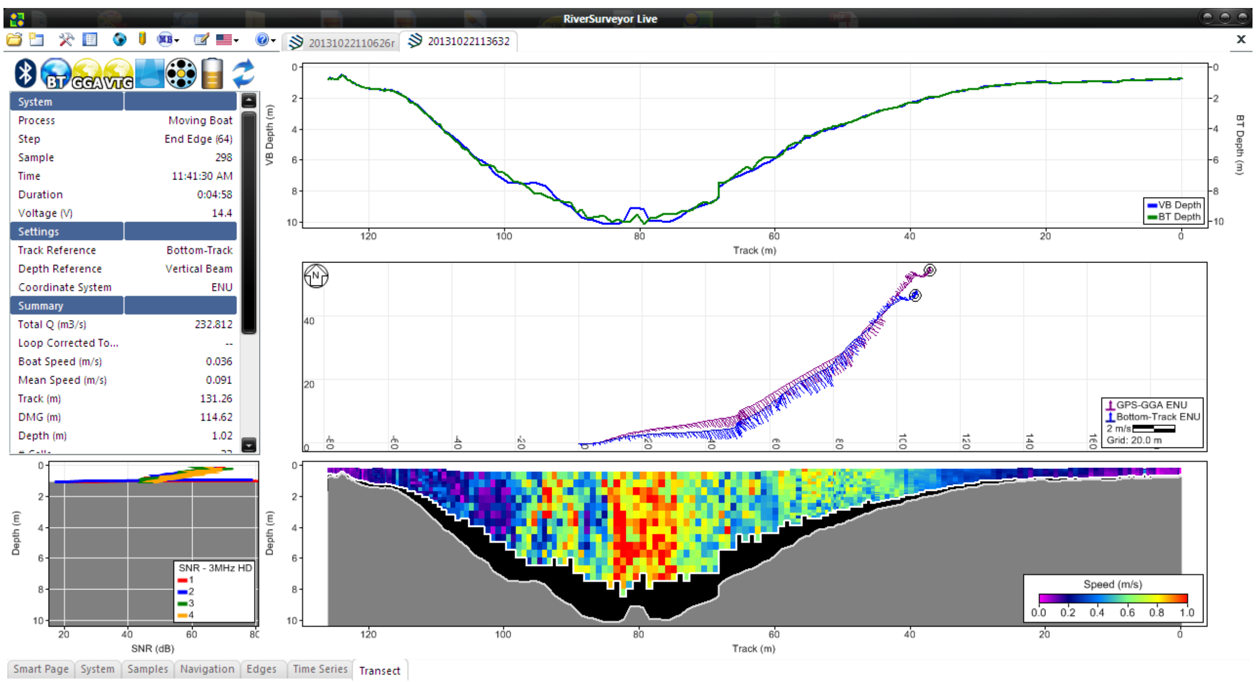


***Figure 4a*. Cross-section and Discharge from *RiverSurveyor* using ADCP Method (1st trial)**

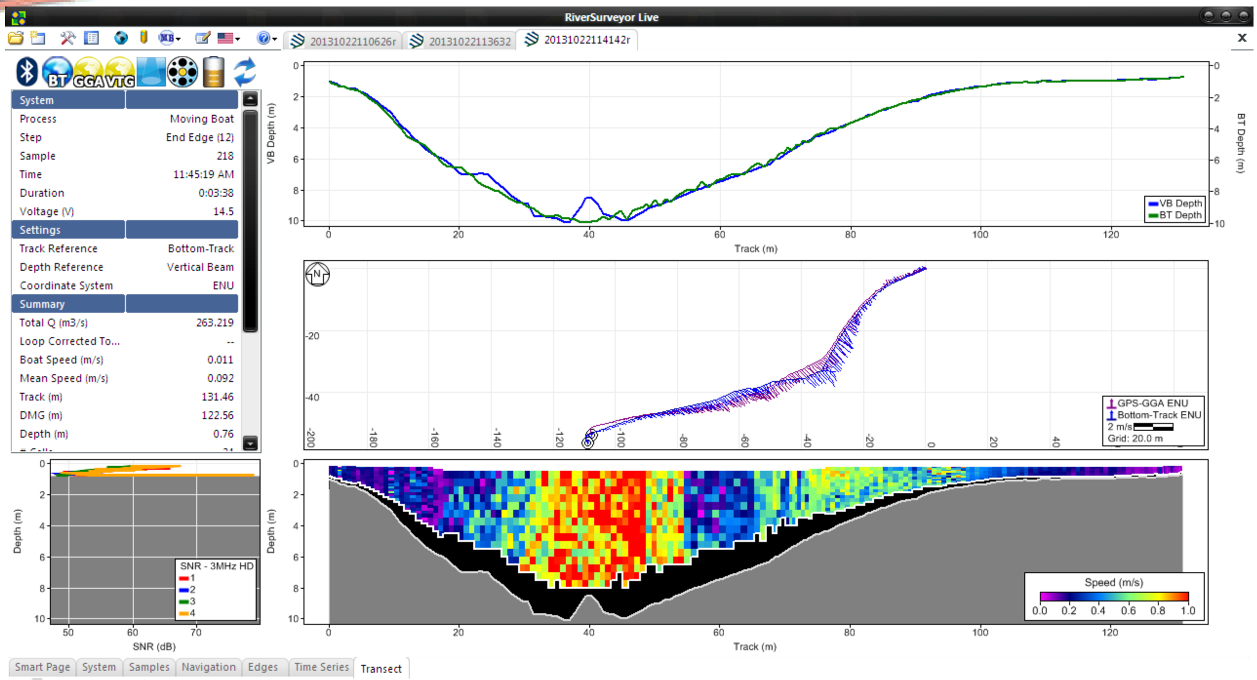


***Figure 4b*. Cross-section and Discharge from *RiverSurveyor* using ADCP Method (2nd trial)**

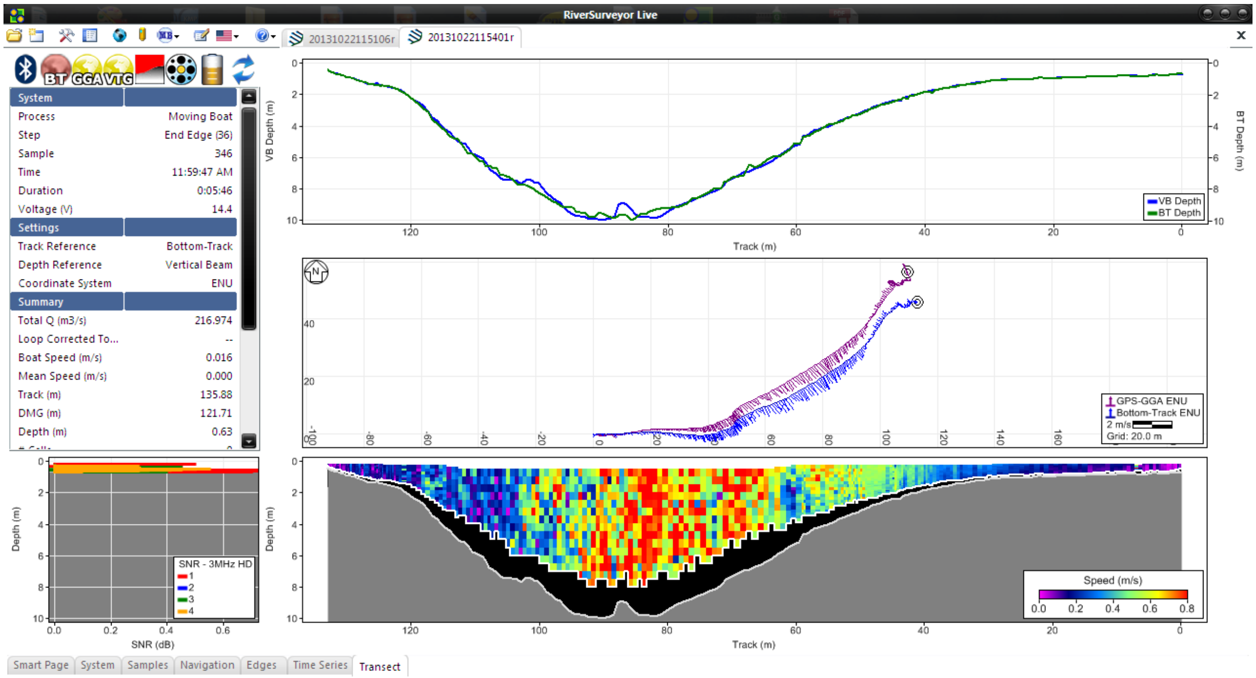


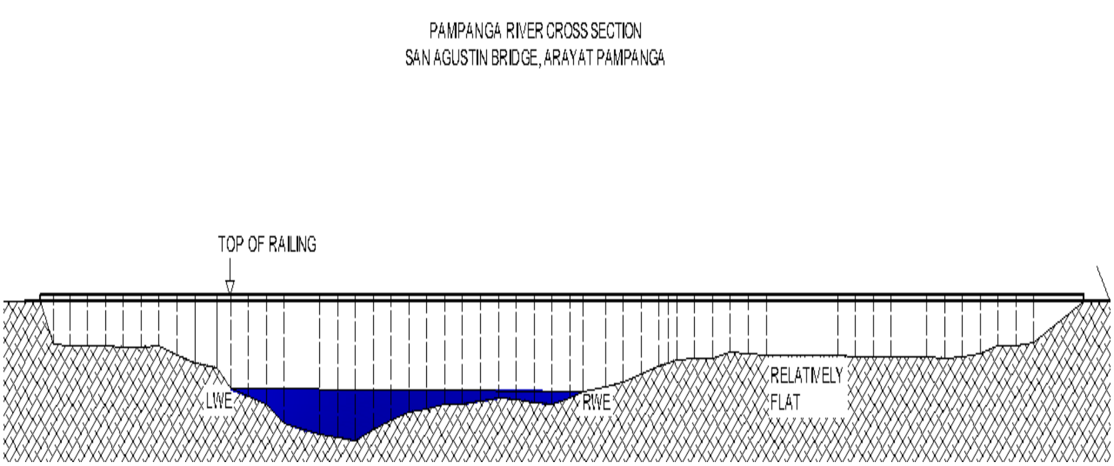
***Figure 4c*. Cross-section and Discharge from *RiverSurveyor* using ADCP Method (3rd trial)**

The *RiverSurveyor®* screen shows the System, Settings, and Summary on the left part and the vessel track and river cross-section on the right. Based on the similarity of the obtained cross-sections (lowest graph on the right), it can be said that the profile of the stream bed is accurate. The colored sections represent water and its velocity, where the red pixels represent flows of up to 0.8 meters per second. The black areas touching the stream bed is also noticeable. These are waters of the river with velocities that could not be determined by the ADCP. Nonetheless, an equivalent discharge for each trial was obtained.

Based on the three trials, with discharges equal to 232.812, 263.219, and 216.974 cumecs respectively, the average discharge is equal to 237.668 cumecs. This is a low discharge compared to the previous methods done due to a sudden drop in the water level of the river during that day.

THE RATING CURVE

On the last day of the field work, Group 1 is tasked to take measurements on the bed profile from the top of the bridge assuming the bridge is perfectly horizontal. Below is the CAD illustration of the entire length of the bridge from bank to bank.



PAMPANGA RIVER BED PROFILING
Arayat, Pampanga

Start Time: 1342 HH
End Time 1405 HH
Date: Oct. 23, 2013

Bridge Measurements:
Heigth of Railing to Curb: 0.75 m
Height of Curb to Ground Level: 0.16 m

Measurements are taken from Top of the Bridge Railing, Left To Right of the Banks.

Station Interval	Depth (m)	Accumulated Horizontal Length (m)	Remarks
0	0.91	0	top of dike
3.8	7.6	3.8	Foot of dike
4.54	7.8	8.34	
5	7.8	13.34	
5	7.97	18.34	
5	7.97	23.34	
5	7.89	28.34	
5	9.26	33.34	
5	10.4	38.34	
5	11.17	43.34	
6.2	14.55	49.54	Left Water Edge
3.8	15.57	53.34	
5	16.86	58.34	
5	19.88	63.34	
5	21.63	68.34	
10	21.57	78.34	Edge of Pier
5	21.94	83.34	
5	22.48	88.34	
5	20.7	93.34	
5	19.39	98.34	
5	18	103.34	
5	17.63	108.34	
5	16.99	113.34	
5	16.79	118.34	
5	16.39	123.34	
5	15.97	128.34	
5	16.02	133.34	
5	16.51	138.34	
5	16.84	143.34	
5	15.78	148.34	
3.8	14.83	152.14	Right Water Edge

Station Interval	Depth (m)	Accumulated Horizontal Length (m)	Remarks
6.2	14.18	158.34	
5	13.36	163.34	
5	12.22	168.34	
5	10.95	173.34	
2.5	10.41	175.84	
2.5	9.93	178.34	
5	9.91	183.34	
5	9.91	188.34	
5	8.87	193.34	
5	9.16	198.34	
5	9.33	203.34	
5	9.33	208.34	
5	9.33	213.34	
5	9.33	218.34	
5	9.33	223.34	
5	9.59	228.34	
5	9.56	233.34	
5	9.56	238.34	
10	9.46	248.34	
5	9.71	253.34	
5	9.63	258.34	
5	9.05	263.34	
5	7.9	268.34	
5	7.77	273.34	
5	7.4	278.34	Foot of dike
14	0.91	292.34	top of dike

Elevation data of the river bed from top of the bridge

The data above is then converted to the mean sea level elevation based on the benchmark from the old PAGASA gaging station situated in the area. Using the excel suite, the rating equation is deduced.

This rating curve equation governs the change in the discharge (Q) of the river at any change of stage. So with this equation, the discharge of the water is predictable and can be used in simulation software like HECRAS.

The rating curve illustrates the discharge versus stage relationship of a river. By the nature of the bed profiles, rating curves of any river is different from the other.

Rating Curve Development for				Pampanga River			
	Measuring Station:		Arayat Station				
	Drainage Area:		6487				
	River:		Pampanga River				
	Location:		San Agustin Bridge, Arayat, Pampanga				
	Elev. S.G."0" rdg.=		0.000	meters			

Meas. #	Day	Month	Year	S.G.(m)	Q(m^3/sec)	Remarks
				15.402	6731.219	
				14.000	5488.026	
				13.000	4665.799	
				11.000	3186.386	
				10.000	2534.263	
				9.000	1943.296	
				8.000	1588.867	
				7.000	1446.523	
				6.000	1244.836	
				5.000	1001.068	
				4.000	769.036	
				3.000	566.342	
				2.000	398.449	
				1.000	264.299	
				0.500	205.881	
				-1.000	130.644	
				-2.000	84.195	
				-3.000	44.612	
				-4.000	18.203	
				-5.000	2.871	

Q = 0.306 [H - (-7.39)] 3.190

The Rating Curve Equation !!!

Summary test for Ho . . . . . .

Ho	a	b	Sx^2			
-7.50	0.26	3.239	159.0038	Minimum	Sx^2 =	157.77577
-7.39	0.31	3.190	157.7758			
-7.28	0.36	3.140	160.9545			
-7.17	0.42	3.090	169.2081			
-7.06	0.49	3.039	183.3305			
-6.95	0.58	2.986	204.2726			
-6.84	0.68	2.933	233.1833			
-6.73	0.81	2.879	271.4649			
-6.62	0.96	2.824	320.8478			
-6.51	1.14	2.767	383.4949			
-6.40	1.35	2.708	462.1486			
-6.29	1.62	2.648	560.3451			
-6.18	1.94	2.586	682.7326			
-6.07	2.34	2.521	835.5621			

The rating Curve equation and the Ho test

The rating curve equation, from the given set of stage-discharge values, is:

$$Q = 0.306\ (H+7.39)^{3.190} \text{ cumecs}$$

INSIGHTS

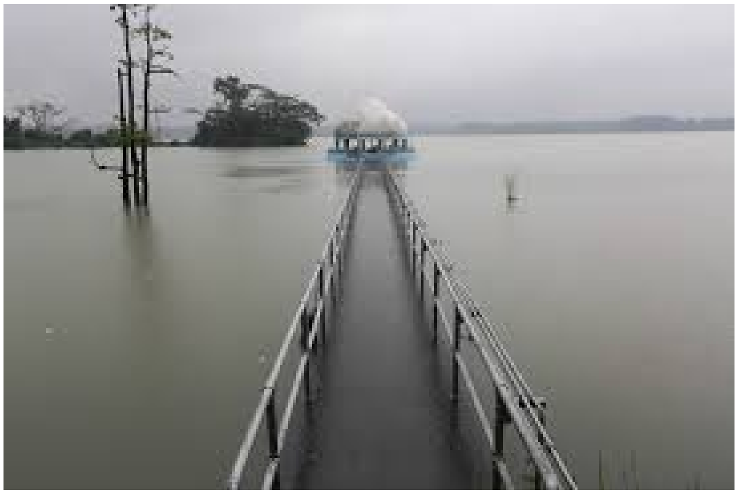
The four-day field work, in general, is a tiring yet fun experience that any aspiring hydrologist should not miss. Each of the four methods offered a different approach in measuring stream discharge, without hang-ups from the lack of equipment or time restraint. Working in groups of eight is also good enough, since any one member will always have something to do. You generally work while you learn, which is a rare find compared to college-day experiments.

Since the overall management and facilitation of the field work is already satisfactory, most of the personal suggestions would be regarding the materials and equipment used during the field work, though the solutions would mostly require funding. For the four discharge measurement methods, except ADCP method, it could be suggested to:

1. Have a larger (and functioning) sounding reel for the deeper portions of the river cross-section during current meter method;
2. Obtain more cross-sections (thus, more bamboo floats) during the float method so that discrepancies will be compensated especially with missing floats; and
3. Have a cableway or a fixed rope with markings that will serve as a tagline in slope-area method.

Other suggestions may be finding a way to cook meals to save from eating in fastfoods as well as more time allowance to learn from all the gathered data after the field work.

VI FIELD VISITS


Then La Mesa Dam

La Mesa Dam

The La Mesa Watershed is the first destination, and the first of the four dams visited during the field work. The visit to the dam includes a brief discussion of how significant is the La Mesa watershed from the waters processed by Manila Water and Maynilad, to the waters consumed by residents of Metro Manila.


The Pantabangan Dam

Pantabangan Dam

The visit to Pantabangan Dam was literally warm but welcoming. The nearly four-hour trip to the dam was compensated with a sophisticated ambience of the hall and a heavy snack. In addition, the flood forecasting and warning center for dam operations of Pantabangan has a mix of modern and old school facilities. Above all, the dam's watershed and spillway turned out to be a breathtaking landscape. It was very nice taking pictures within the area.


Subic Bay fish sightings

Subic

A free day at Subic in Zambales did not turn out as fruitful as everyone had expected. The bus had a few stops in Camayan Beach Resort for picture-taking and in Duty Free Freeport Exchange for shopping.

Cong Dadong Dam

Cong Dadong Dam was visited right after the third field work. It was located upstream of Pampanga River from San Agustin Bridge, a few kilometers away. The dam was said to be mainly for irrigation purposes, thus, its construction is fairly simple compared to other dams.

Calumpit/Bacolor/Clark

First of the three trips during Day 9 is the Municipal Disaster Risk Reduction and Management Council (MDRRMC) in Calumpit, Bulacan. The town of Calumpit claims itself to have flood-loving people. This is the reason why they came up with a flood monitoring system using Microsoft Excel Suite. This is an impressive move on the part of the municipality of Calumpit and a good initiative for other nearby towns to follow suit.

Next stop is the San Guillermo Parish Church, also known as the Sunken Church of Bacolor in Pampanga. By the name itself, it was noticed how the church sank by a few meters after the Mount Pinatubo eruption in 1991, giving the impression that it has a low elevation. However, it was admirable to see how the church was saved and still preserves its historical attributes.

Last stop for the day was the tour of Clark Freeport Zone near Angeles City, Pampanga. The place is best known for its airport and leisure hubs, but the group decided to stop again at Duty Free. Clark looked clean and peaceful in general.

The San Guillermo Parish Church of Bacolor *Angat Dam Spillway*

Angat Dam

The last destination of the field work and the last of the four dams is the Angat Dam in Norzagaray, Bulacan. The way to the dam, as well as its landscapes and spillway, is closely similar to that of Pantabangan dam. However, the trainees were given a closer look inside the Angat Hydroelectric Power Plant. We have seen the enormous 50 Megawatt Alternators connected to the turbine. The generation as well as the transmission system was explained by one of the engineers.

RELATING HTC WITH THE FIELD VISIT

As a hydrologist trainee, it is important that we were able to visit the dams around Central Luzon as there are chances of career opportunities there one day. There are a few ways that relate hydrology to dam operation. It all starts with the concept of streamflow.

For all we know, rivers tend to change its flow rate at any moment in time. This could likely put the communities and vegetation downstream of the river into danger. Dams, particularly storage dams for this purpose, could control these changes in flow by storing a huge amount of water that may be released for future use. Other dams can also divert the streamflow from the main river, directing part of the water for irrigation and vegetation. Finally, some dams come with hydroelectric power plants that supply electricity to communities surrounding the dam. Thus, hydrologists should carefully monitor and control the inflow and outflow on these important watersheds.

Hydrologists designated on flood forecasting are a big help for dam operations as they monitor water level and discharge of major rivers downstream. Moreover, hydrologists designated on flood warning for dam operations help the community be warned of the possible dangers of immediate streamflow.

VII CONCLUSION

Based from the given objectives, the following conclusions were drawn:

1. The group was able to perform the four methods of discharge measurement along Pampanga River in San Agustin Bridge, Arayat, Pampanga. All methods were done on four separate days on a normal weather condition as follows:
   a. Current meter method is the most common among the methods for measuring discharge. In this method, a stream channel cross-section is divided into numerous vertical subsections and the water velocity is determined using a Price AA current meter.
   b. Float method is the most preferred over other methods in terms of practicality during high flows. The idea is to measure the time it takes for a buoyant object to float downstream from one cross-section to another. While float method is observed as very simple, it may be prone to glitches especially when the dropped objects do not float.
   c. Slope-area method is the most tedious of the discharge measurement methods. Three cross-sections, each from one reach to the other (flood marks) were selected downstream from the bridge. The horizontal distance (HD), elevation (VD), and vertical angle (VA) were then determined using a total station and a reflecting prism.
   d. The Acoustic Doppler Current Profiler or ADCP method is likely the most sophisticated, most efficient, and most accurate among the four methods. ADCP made use of the Doppler Effect to measure the velocity of water as well as acoustics in order to measure water depth.

2. Determining the discharge for each method requires computation, either manually or with the use of Microsoft Excel Suite. River profiles were also drawn using cross-section paper and other drafting software:
   a. In the current meter method, recorded data were simply inputted and the immediate velocity, area, corrected angle, and discharge were automatically computed in a programmed Excel table. Practically, the

discharge in each subsection is the product of the subsection area and the velocity. The total discharge is then the sum of the discharge of each subsection.

b. Float method requires manual computation of discharge. The subsections and their corresponding depth comprise the area, whereas the velocity is the time travelled from the first cross-section to the next. Since the method was performed twice, the average of the velocities and time should be noted to come up with the discharge.
c. The stream discharge from using slope-area method could be readily determined using a programmed Excel table, where the left and right bank elevations as well as roughness coefficient were inputted. However, a detailed sketch of the river cross-sections and top view must be taken into account.
d. Discharge measurement using ADCP did not require any data manipulation. After crossing the ADCP, data were automatically transmitted to the receiver end connected to a computer. This is where the detailed river cross-section and the discharge are readily available.

The equivalent discharges of all methods were as follows:

Method	**Discharge (cumecs)**
Current Meter	311.48
Float	614.02
Slope-Area	3440.34
ADCP	237.668

It was noticed that the different discharge measuring methods resulted to different discharge values. This is likely due to the nature of accuracy of each method and differences in water levels for each day. A proof of this is the fact that the discharge of one group doing a certain method is different from another group doing the same method on another day. Another is the fact that the discharge of one group doing a certain method is different from another group doing a different method on the same day.

3. Stage-discharge relations are developed for streamgages by physically measuring the flow of the river. The rating curve of Pampanga River reveals that for each measurement of discharge there is a corresponding measurement of stage. And as the stage increases, the equivalent discharge increases, at a rate that is getting higher as the depth approaches the uppermost portions of the cross-section.

   Special effort is made to measure extremely high and low stages and flows because these measurements occur less frequently. The stage-discharge relation depends upon the shape, size, slope, and roughness of the channel at the streamgage and is different for every streamgage.

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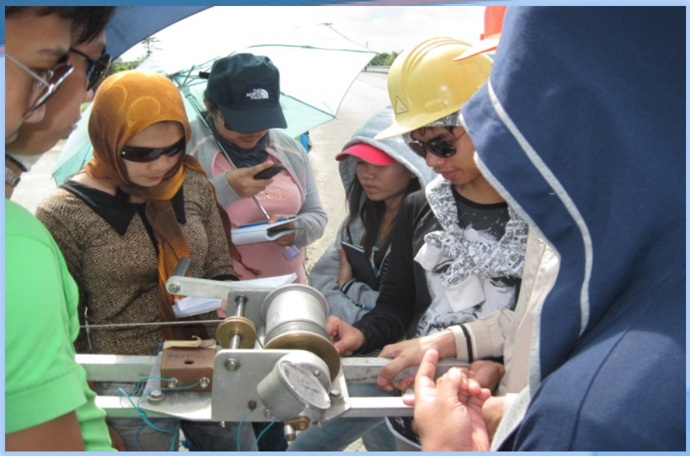

Current Meter Method on the bridge

Taking the horizontal width of the river using a range finder.

Measuring the depth using the Echo Sounder

Taking the profile of the banks using the Total Station.