Summary Report on 10 days Fieldwork at Arayat, Pampanga River, Pampanga, Philippines

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Submitted to:

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I. INTRODUCTION

The main task of hydrologist is to work in the field particularly in the river. It is where hydrologist monitors the water level of the river for safety reasons when flood occurs. It would mainly measure the flow/discharge of the river using different methods in the field.

It was on the midst of a very scorching heat of the sun on October 15-24, 2013, when Hydrologists Training Course 2013 was given a chance to do a fieldwork at San Agustin Bridge, Pampanga River, Brgy. Camba, Arayat. This is a great opportunity for the trainees to practice the theories learned in the class into real situations. The class were divided into 4 groups and tasked to do a method per day. There are 4 methods used; ADCP, Convention Current Meter (on the bridge), float method and Slope Area method.

The weather was hot as if we're having our skin tan and work on progress in a zero rainfall that made the water receding as the day goes by. A month ago, the area experienced severe flooding that caused inundation of the flat area upstream and downstream of the bridge. Traces of high water level marks, debris, silt and loam soils are noticeable. The water is composed of sandy, gravel and some 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 silt in soil that some are buried on it.

Objectives

At the end of the fieldwork, we are able to perform the four methods with the proper use of the different devices as well, measure the volumetric flow rate and mean velocity using various methods of discharge measurements, able to compare the different methods perform and to come up the discharge of water and to show the relation between various stages of the river cross-section with its equivalent discharge


The picture shows the banks of the river and the water. As the days goes by the water level becomes low.


II. LOCATION OF THE SITE

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.

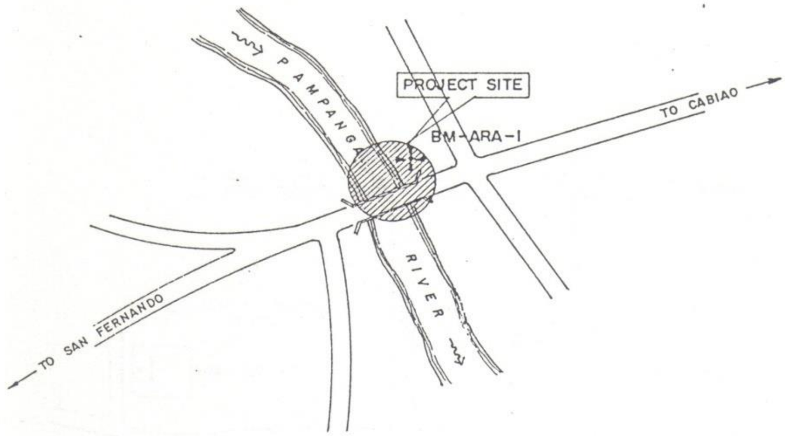
Its headwaters are located at the Sierra Madre and runs a south and southwesterly course for about 260 kilometers until it drains into Manila Bay.

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.

LOCATION / ACCESS

Station can be reached by passing national highway No. 10 from Sta. Ana town to Arayat town leading to Arayat concrete bridge, about 100 meters NW of Arayat bridge.



RECORD OF B.M.

DESIGNATION : BM-ARA-1
ELEVATION : 9.114 (MSL)
ESTABLISHED BY : Technotest, Inc.
DATE : Feb., 1987

RECORD OF B.M.

DESIGNATION :
ELEVATION :
ESTABLISHED BY :
DATE :

DESCRIPTION OF MARK

BM-ARA-1 is in the province of Pampanga, town of Arayat located at the corner of the concrete foundation of the antenna post. Mark is a 3" concrete nail embedded in a drilled hole with inscriptions on the cement putty thus, "FFWSDOP BM-ARA-1, 1987." El. of mark 9.114

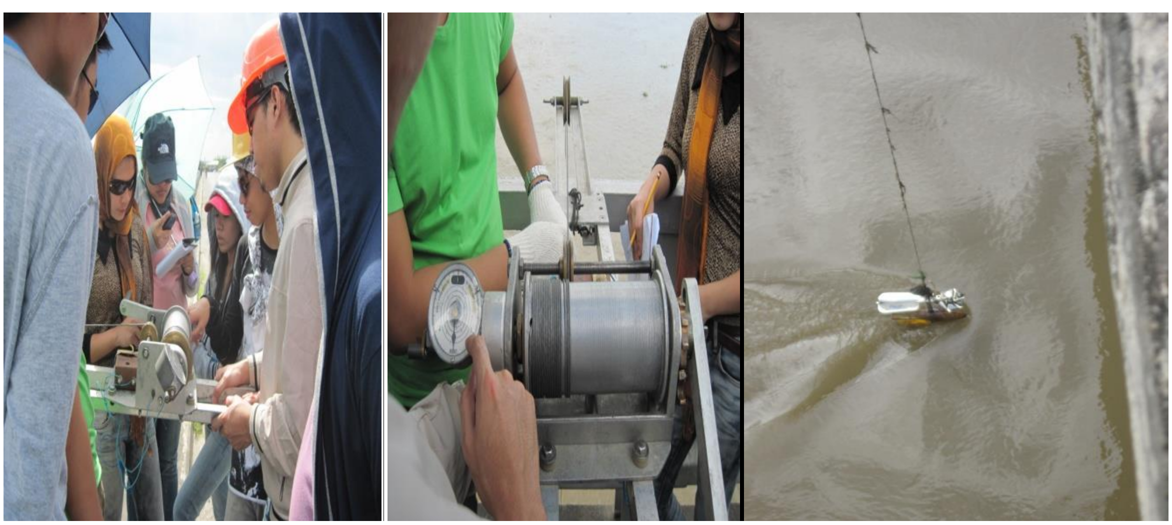
PMP	STATION INFORMATION SHEET
3	ARAYAT RAIN / WATER LEVEL GAUGE STATION

III. METHODOLOGY

Conventional Current Meter (on the bridge)

A current meter measurement derives its name from the fact that it uses some type of current meter to measure stream velocity.

This was done on the first day. The San Augustine Bridge was divided into several 5 meters distance in verticals from the total width of the river. It starts from where the water edge of the left water bank and ends up in the right water bank. But before starting the activity, 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. It was then tested if it still works. The current meter was brought down thru a cable until it reaches the water surface starting the first vertical. The height of the bridge was measured to the water surface and recorded. From the water surface the current meter was lowered until it reached the river bed and 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. These were done actually by counting the beep (1 beep per 5 revolutions) within 60 seconds after the device was stabilized on that point in the water. This was continuously done until it reached the right water bank. The results of 0.2, 0.6 and 0.8 measurements will give an average value and will be used as the mean velocity of the particular vertical observation. The data measured will then be filled up to the forms given on the current meter to get the discharge.



Indirect Method by float

This method was done on the second day of our group. The following are used in this method; stop-watch, tape measure, stakes for anchoring tape measure to stream banks, sounder to measure water depth, 10 pcs x 0.5m bamboo as visible buoyant objects, notebook for recording purposes and stakes for anchoring tape measure to stream banks.

The straight reach (with minimum turbulence) of at least 50m from the downstream of the bridge was selected and identified. In our case we measured 53m. It was then marked for the “start” and “end” points of the reach with 100-meter long additional. Marked 5 drop points along the bridge starting from the river centerline. Then the bamboo was dropped into the stream from the downstream of the bridge. The timer was started when the object crosses the starting point and stopped the timer when it reached the end point along the reach. This was being done twice on each dropping point and each reading on the timer was recorded. See figure below.

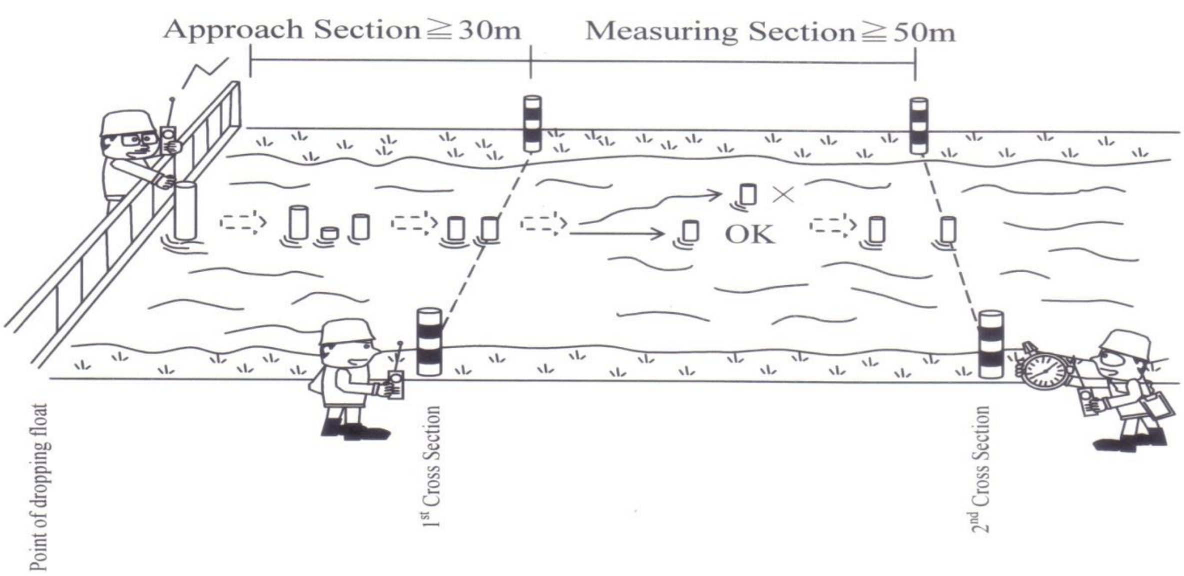


Figure-4 Discharge Measurement by Float

Using an echo sounding device the river's cross section was obtained. 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. These values will then used and input into the forms given to get the discharge.

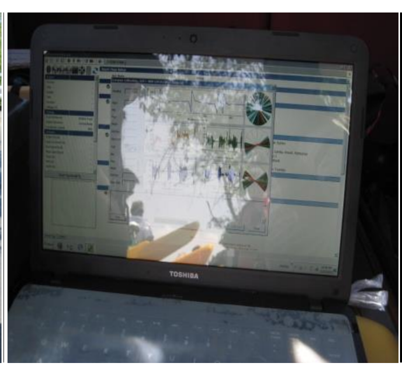
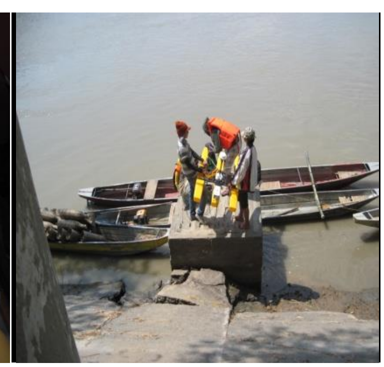
Slope-Area Method

There are three cross section in this method. The area 50m 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 were repeated in sections 2 & 3. An echo sounder was used to get depth of the water and to make a straight line using a total station. In the total station, the vertical and horizontal distance was measured and also the angle. These values were input to the forms given and the discharge was determined.

Acoustic Doppler Current Profiler (ADCP)

The ADCP instrument was assembled by mounting the sensors on a meter long, orange-colored plastic vessel. Using the laptop the ADCP was calibrated on its pitch, roll and yaw axes. After the instrument was assembled and calibrated, it was positioned approximately 50m upstream of the bridge and was tow by a banca across the river thrice for data acquisition. The instrument transmit into the water and use the returning sound to measure parameters such as water velocity, river depth and boat speed. These values are automatically registered in the laptop using a specific operating system where the discharge was determined. The discharge was determined by averaging the 3 values of the measured discharge.

IV. RESULT AND DISCUSSION

Stream flow, when it occurs in excess, can create a hazard – floods caused extensive damage and hardship. Records of flood events obtained at gauging stations serve as the basis for the design of bridges, culverts, dams and flood control reservoirs, and for flood plain delineation and flood warning systems.

Hydrologists are very crucial especially when flood occurs. It is their responsibility to monitor the water level of the river to prevent losses of lives and properties when flood strikes in the area. They will be the one who gives information to the local authority if the water is risky or at its highest discharge so the people will be warn to evacuate. It is important in Pampanga River basin to be monitoring especially that this area is very risky in severe flooding. Basin experiences, on an average, at least one flooding in a year. The dry season generally occurs from December to May, and wet the rest of the year. The wettest months are from July to September. The Pampanga River Basin could handle between 100-130mm of 24 Hour Rainfall. With this kind of work, various methods are associated to measure the discharge. This is what we did in our 10 days fieldwork in Pampanga River, San Augustine Bridge, Arayat, Pampanga to have an actual measurement of the discharge. The four methods are Conventional Current Meter (on the bridge), Indirect Method by float, Slope-Area Method and Acoustic Doppler Current Profiler (ADCP).

Conventional Current Meter (on the bridge)

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.

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

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)	Velocity 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 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). Which in our case we only get 3 angles more than 4 degrees.
- 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)

Table 1 shows the result of the measurement on current meter. It is noticeable that not all depth are filled up this may be due to piers, water lilies, and turbulent flows that hindered in getting an accurate number of revolutions at a certain time. All the information in the table was filled up with the value get from the measurement.

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, and may be due to insufficient data along the piers and other obstructions below a subsection.

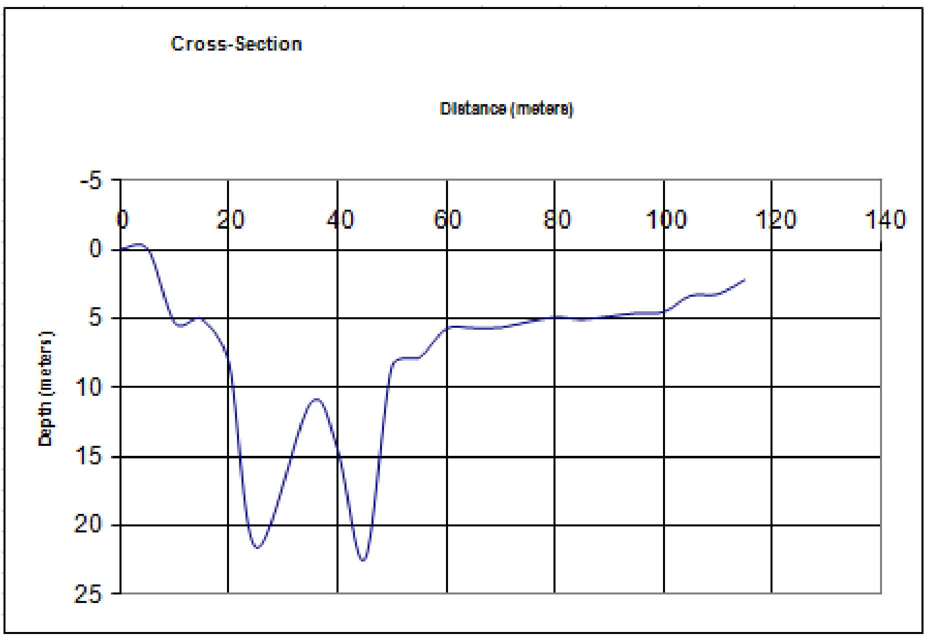


***Figure 1*. Pampanga River Cross-section Derived from Distance-Depth Relation**

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.

Indirect Method by float

The velocity of the float is equal to the distance between the cross sections divided by the time of travel. The mean velocity of flow in the vertical is equal to the float velocity multiplied by a coefficient that is based on the shape of the vertical-velocity profile and relative depth of immersion of the float.

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.

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

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**						

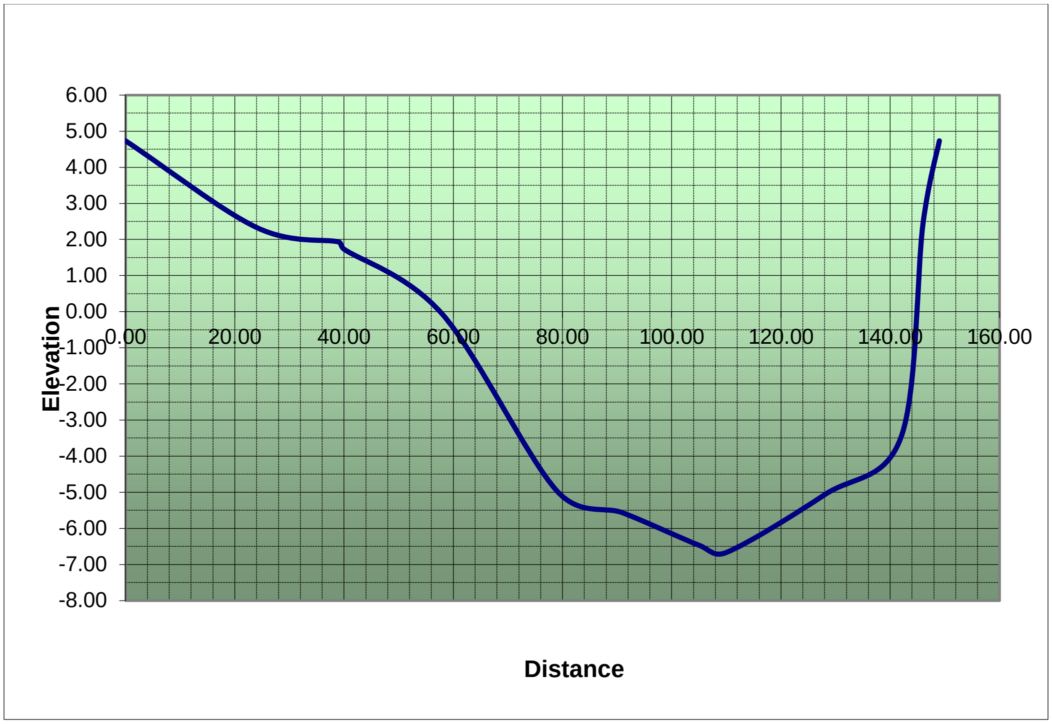


Figure 2. **Equivalent First Cross-section using Distance and Elevation**

***Table 3*. Physical Parameters for the Second Cross-section using Float Method**

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**

Figure 3. **Equivalent Second Cross-section using Distance and Elevation**

Table 4.**Discharge (Q) Table for the Two River Cross-sections using Float Method**

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		

Float method shows a similar, but simpler approach compared to the slope-area method. Microsoft Excel Suite may be used (Tables 2 and 3) in determining the total width, area, wetted perimeter, hydraulic radius, mean depth, and a graphic representation of the cross-sections (Figures 2 and 3).

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 3 was manually computed, revealing a total average discharge of 614.02 cumecs. This is roughly 2 times higher compared to the discharge measurement using current meter method.

Slope-Area Method

The Slope Area-Method is commonly used to measure peak discharge indirectly. The Slope Area-Method indirectly measures peak discharge from high water marks and/or debris lines after the event.

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.

***Table 5*. Physical Parameters of the 1st Cross-section Using Slope-Area Method**

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**				

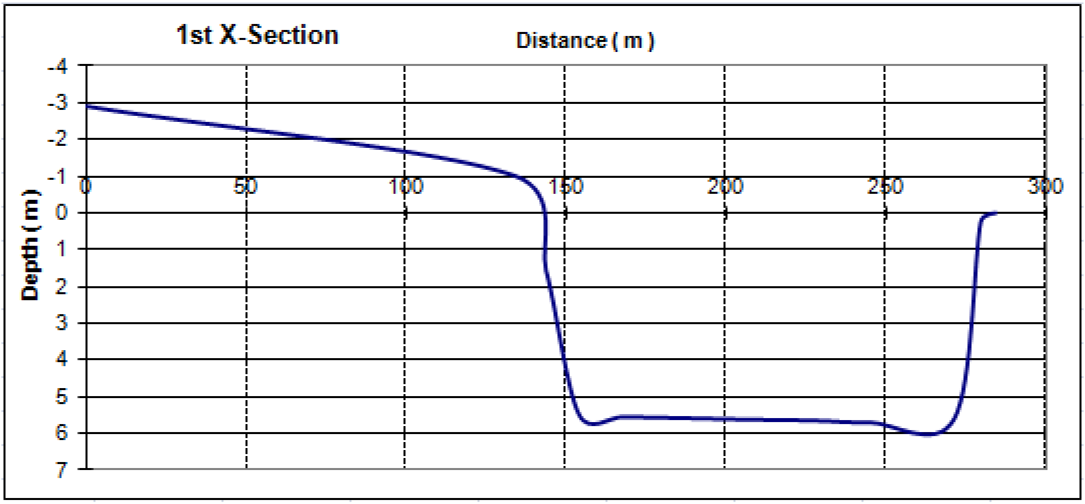


Figure 4. **Graphic Representation of the 1st Cross-section Using Distance-Depth Relation**

Table 6. **Physical Parameters of the 2nd Cross-section Using Slope-Area Method**

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**				

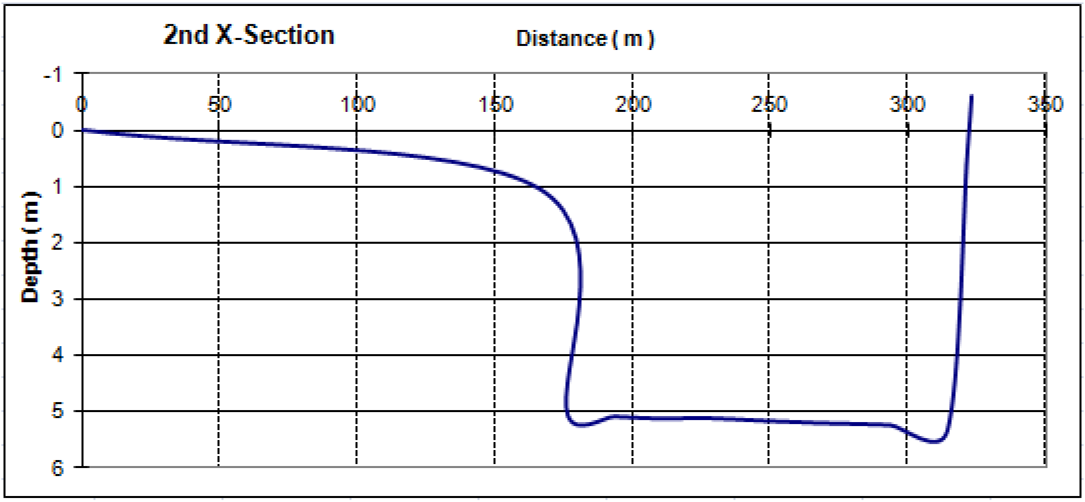


***Figure 5*. Graphic Representation of the 2nd Cross-section Using Distance-Depth Relation**

***Table 7*. Physical Parameters of the 3rd Cross-section Using Slope-Area Method**

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**				

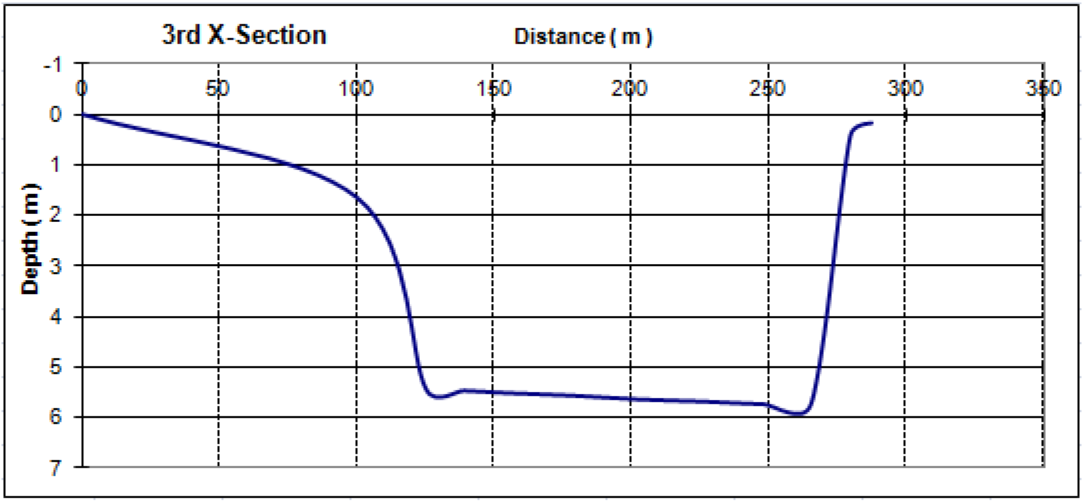


Figure 6. **Graphic Representation of the 3rd Cross-section Using Distance-Depth Relation**

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 5, 6, and 7. The total width, area, WP, hydraulic radius, and mean section depth shall also appear at the bottom of these tables.

Figures 4, 5, 6 shows the graphic representation of the three cross-sections using the parameters of depth and distance. Comparing Figures 4, 5, 6 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.

Table 7. **Slope-Area Summary Sheet of the Three Cross-sections**

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

❖❖

X - Section Properties: hth/97

			Highwater Marks										
X-Sect.	Width	Area	Left Bank	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)

		h_v							
Reach	Assumed Q	U/S	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:

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.

Acoustic Doppler Current Profiler (ADCP)

The USGS has been measuring river discharge with ADCPs since the early 1990s (Oberg and Mueller, 1994). ADCP use has been limited mainly to rivers with depths greater than about 4 feet. Because of recent advances in ADCP technology, these instruments have the potential to be used in shallower rivers. ADCPs measure three-dimensional velocities at numerous points in the water column. ADCPs also measure water depth and track the movement of the ADCP unit with respect to the channel bed or with the use of a Global Positioning System (GPS). The measured depth, velocity, and position data are used to calculate the discharge through software applications. A discharge measurement using an ADCP can be made in a timelier manner when compared to the use of a conventional meter.

The *River Surveyor®* 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:

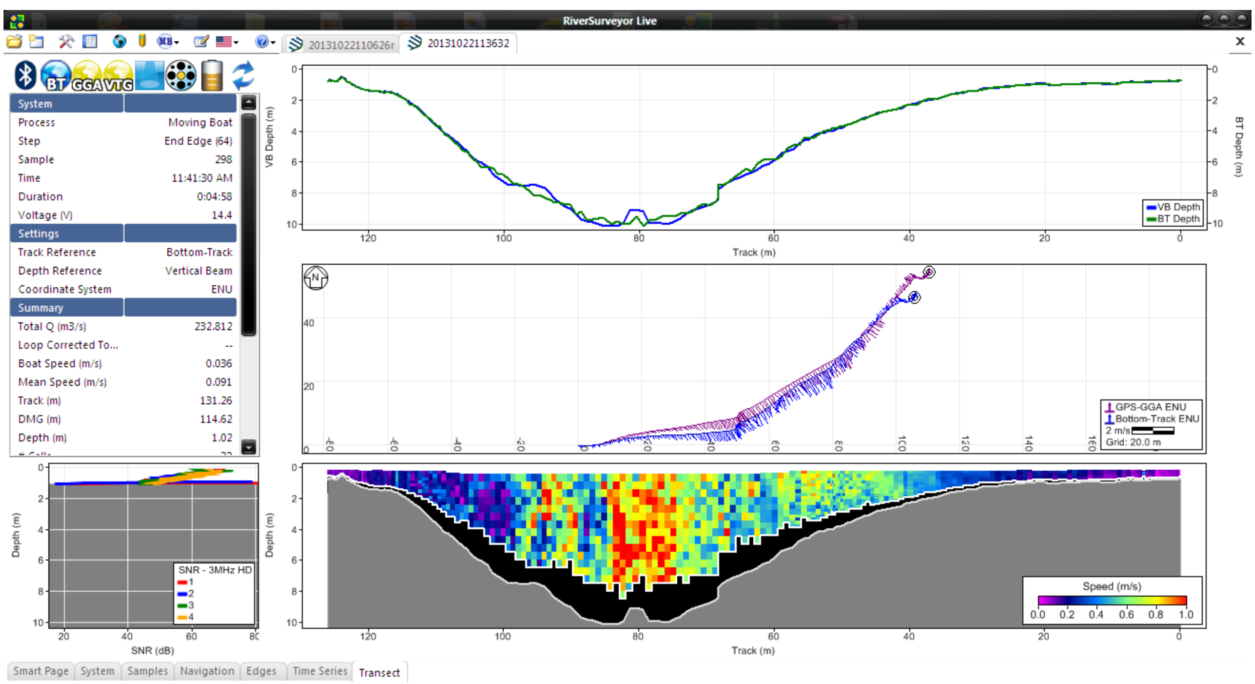


***Figure 7*. Cross-section and Discharge from *River Surveyor* using ADCP Method (1st trial)**

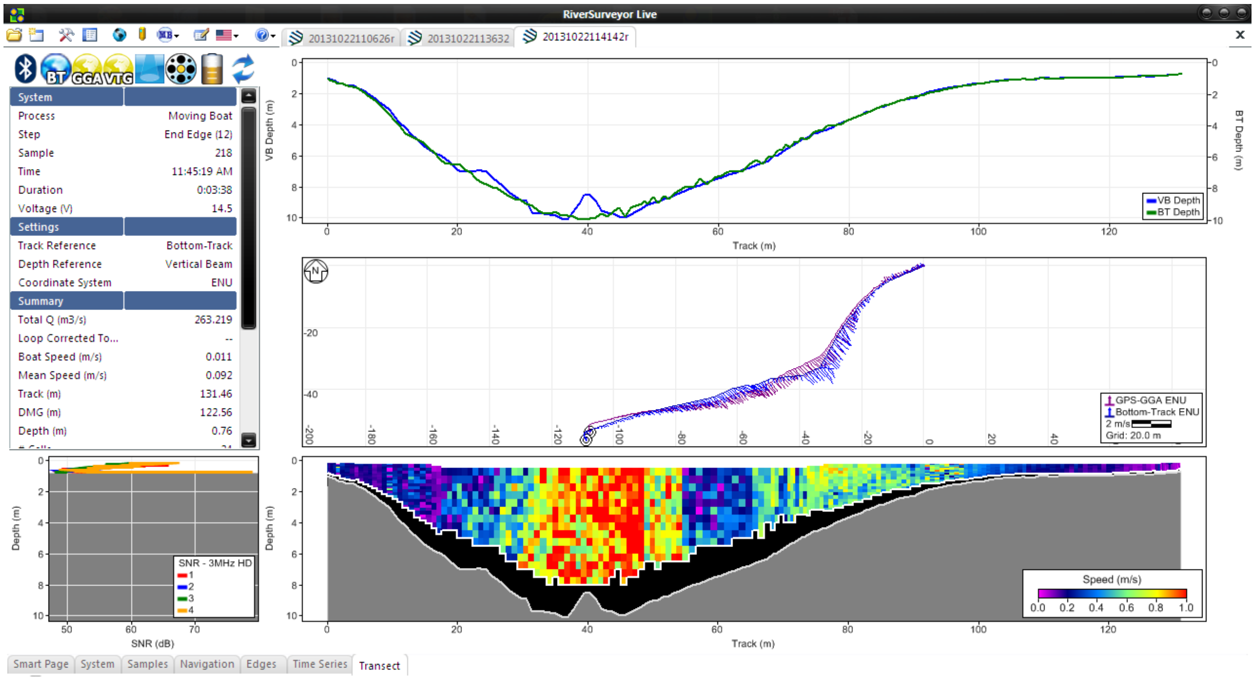


***Figure 8*. Cross-section and Discharge from *River Surveyor* using ADCP Method (2nd trial)**

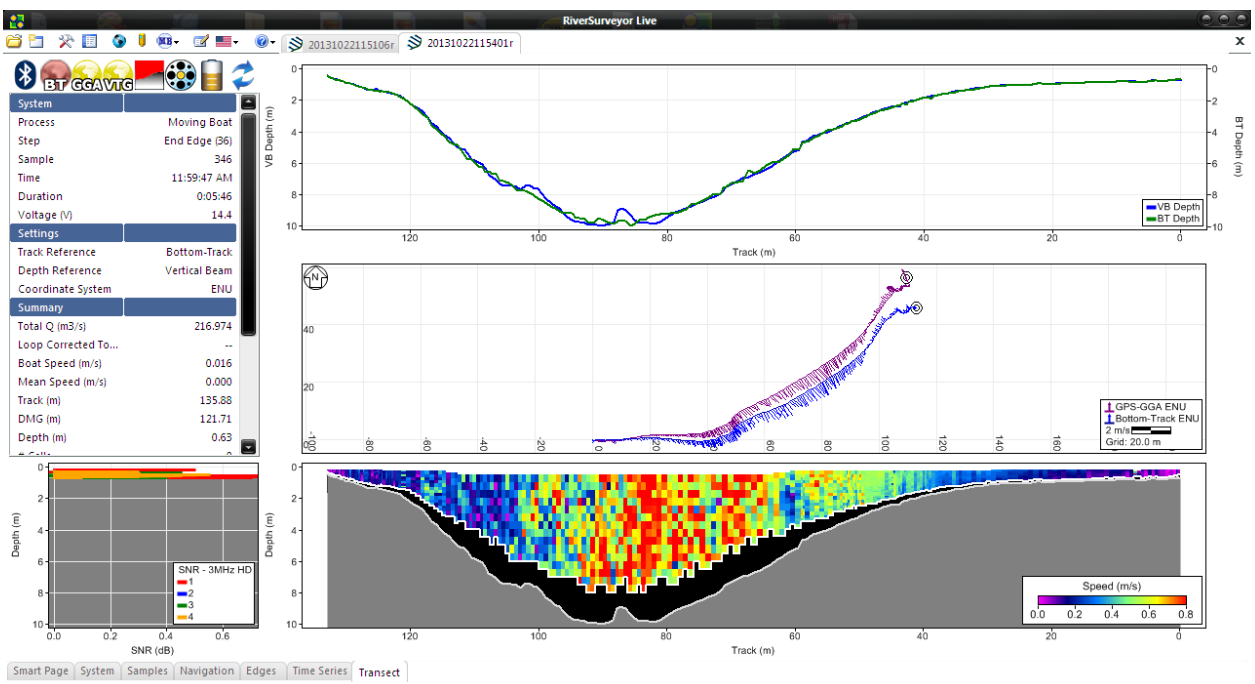


***Figure 9*. Cross-section and Discharge from *River Surveyor* using ADCP Method (3rd trial)**

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.

Table 8. Advantages and disadvantages of the four methods.

Methods	Advantage	Disadvantage
Conventional Current Meter (on the bridge)	• 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.	• Tedious • If there are floating objects like water lilies or algae along the river the rotation of the bucket wheel will obstruct. • If the current of the river is very slow the bucket wheel will not rotate. • Conventional current-meter methods take multiples of time.
Indirect Method by float	• Simple and inexpensive • Good for fairly straight reach. • It can be used where flood measurements are needed and then measuring structure has been destroyed or it is impossible to use a meter	• Floats have very limited use in stream gauging • Not applicable in critical level for the float tends to be stocked on the river bed. • Wind may adversely affect the accuracy of the computed discharge by its effect on the velocity of the floats, especially if velocity is very slow.
Slope-Area Method	• 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.	• Tedious to perform.

Acoustic Doppler Current Profiler (ADCP)	• The main advantage of the ADCP technology in comparison to the well-established current meter method for water velocity and discharge measurements is the character of data that is obtained. • ADCPs provide a continuous data collection throughout the water column and cross section rather than discrete point measurements. • The "current profile" outputted by the ADCP associated software is closer to reality than vastly extrapolated cross-section data that can be achieved with current meters. • In addition, the ADCP method does not only measure velocity but also the measurement profile. • Measurements are more cost effective because less staff is required and time taken for each measurement is reduced. • Transport of the instrument and accessories is very easy and can be done by the measurement team themselves.	• Expensive

The Rating Equation

From the previous calculations, a set of stage and discharge are now available for the whole range of the cross section. This time, the H-Q values are entered on another excel suite that computes for the rating equation. Shown on the next page are the H-Q values used for the rating equation computations.

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	

After the H-Q Values are entered, the value for Ho (elevation of zero flow) would have to be determined by trial and error on the “rat” tab of the same excel suite:

Summary test for Ho . . . . . .

Ho	a	b	ΣX^2			
-7.50	0.26	3.239	159.0038	Minimum	ΣX^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 value for Ho with the least chi square value would then be chosen as the Ho value in the final equation. In our group, Ho is equal to -7.39 by trial and error. This is then entered back on the previous sheet, under the "Assumed Ho" cell.

Assumed Ho =	-7.39	meters					
S.G. elev. (H)	H-Ho	Log H-Ho (X)	Log Q (Y)	X^2	XY		
15.402	22.792	1.358	3.828	1.844	5.198		
14.000	21.390	1.330	3.739	1.769	4.974		
13.000	20.390	1.309	3.669	1.715	4.804	n =	20.000
11.000	18.390	1.265	3.503	1.599	4.430	Σ (X) =	20.237
10.000	17.390	1.240	3.404	1.538	4.222	Σ (Y) =	54.273
9.000	16.390	1.215	3.289	1.475	3.994	Σ (X^2) =	21.930
8.000	15.390	1.187	3.201	1.410	3.800	Σ (XY)=	59.554
7.000	14.390	1.158	3.160	1.341	3.660		
6.000	13.390	1.127	3.095	1.270	3.488	X_{bar} =	1.012
5.000	12.390	1.093	3.000	1.195	3.280	Y_{bar} =	2.714
4.000	11.390	1.057	2.886	1.116	3.049	$(\Sigma(X))^2$=	409.529
3.000	10.390	1.017	2.753	1.034	2.799		
2.000	9.390	0.973	2.600	0.946	2.529	b^ =	3.190
1.000	8.390	0.924	2.422	0.853	2.237	a^ =	-0.514
0.500	7.890	0.897	2.314	0.805	2.075	a = $10^{a\text{^}}$ =	0.306
-1.000	6.390	0.806	2.116	0.649	1.705	b = b^ =	3.190
-2.000	5.390	0.732	1.925	0.535	1.409		
-3.000	4.390	0.642	1.649	0.413	1.060		
-4.000	3.390	0.530	1.260	0.281	0.668		
-5.000	2.390	0.378	0.458	0.143	0.173		

After this, the completed equation will be shown:

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 !!!

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

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

The Rating Table

After the rating curve equation has been computed, a rating table can be made. This is done on another excel suite that specifically creates a table based on the equation. The constants of the equation and gage height range are entered in the excel file, after which, it automatically gives the table:

Rating Table for:				***Arayat***			Date:	*October 23, 2013*		
River:	*Pampanga*			Location:	*San Agustin, Arayat, Pampanga*					
Elevation of S.G. "0" reading:			*0*							
Rating Curve Equation Coefficients: **a =**				***0.306***	**Ho=**	***-7.390***	**b^=**	***3.190***		
Range of G.H.:		Min. G.H. =		***0***	Max. possible G.H.=			***11.00***		
Remarks:	*readings based on MSL*									
G.H.(m)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	180.59	181.37	182.16	182.94	183.73	184.52	185.31	186.11	186.90	187.70
0.1	188.50	189.31	190.11	190.92	191.73	192.55	193.36	194.18	195.00	195.82
0.2	196.65	197.48	198.31	199.14	199.97	200.81	201.65	202.49	203.34	204.18
0.3	205.03	205.89	206.74	207.60	208.46	209.32	210.18	211.05	211.92	212.79
0.4	213.66	214.54	215.42	216.30	217.18	218.07	218.96	219.85	220.74	221.64
0.5	222.53	223.44	224.34	225.24	226.15	227.06	227.98	228.89	229.81	230.73
0.6	231.66	232.58	233.51	234.44	235.38	236.31	237.25	238.19	239.14	240.08
0.7	241.03	241.99	242.94	243.90	244.86	245.82	246.78	247.75	248.72	249.69
0.8	250.67	251.64	252.62	253.61	254.59	255.58	256.57	257.57	258.56	259.56
0.9	260.56	261.57	262.57	263.58	264.59	265.61	266.63	267.65	268.67	269.69
1.0	270.72	271.75	272.79	273.82	274.86	275.90	276.95	277.99	279.04	280.09
1.1	281.15	282.21	283.27	284.33	285.40	286.47	287.54	288.61	289.69	290.77
1.2	291.85	292.94	294.02	295.11	296.21	297.30	298.40	299.50	300.61	301.72
1.3	302.83	303.94	305.06	306.17	307.30	308.42	309.55	310.68	311.81	312.95
1.4	314.08	315.23	316.37	317.52	318.67	319.82	320.97	322.13	323.29	324.46
1.5	325.63	326.80	327.97	329.14	330.32	331.50	332.69	333.88	335.07	336.26
1.6	337.45	338.65	339.85	341.06	342.27	343.48	344.69	345.91	347.13	348.35
1.7	349.57	350.80	352.03	353.27	354.51	355.75	356.99	358.23	359.48	360.74
1.8	361.99	363.25	364.51	365.77	367.04	368.31	369.58	370.86	372.14	373.42
1.9	374.71	375.99	377.29	378.58	379.88	381.18	382.48	383.79	385.10	386.41
2.0	387.73	389.04	390.37	391.69	393.02	394.35	395.68	397.02	398.36	399.71
2.1	401.05	402.40	403.75	405.11	406.47	407.83	409.20	410.57	411.94	413.31

This section illustrates how rating curve equations are formulated and how rating tables are computed. If the values entered in the rating curve equation excel suite were actual discharge measurements on field, the resulting table will yield more accurate and reliable results.

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.

Field visits and it's related to hydrology

Our first day of the field work was the visit in La Mesa Watershed and Eco-Park. There, we met the assistant manager who gives us a brief discussion about the dam. As what I remember, he stated that La Mesa dam is not to be blame when flood occurs in the Metro Manila as what the folklore pronounce because La Mesa has no gate it is an earth dam. He also discussed about the water treatment because it is their first priority, the domestic water supply. The other uses of La Mesa dam is for irrigation and hydroelectric.

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.

The La Mesa Watershed and Eco-Park consists of the La Mesa Dam and an ecological nature reserve site in Quezon City commissioned in 1929 in the Philippines. It is part of the Angat-Ipo-La Mesa water system, which supplies most of the water supply of Metro Manila. The La Mesa Dam is an earth dam whose reservoir can hold up to 50.5 million cubic meters and occupying an area of 27 square kilometers.

We also visited the Pantabangan dam. We are given a chance to see their flood forecasting facilities. We also see their spillways and enjoying our picture taking there. I was really amazed of their nature and environment.

Pantabangan Dam is an earth-fill embankment dam on the Pampanga River located in Pantabangan in Nueva Ecija province of the Philippines. The multi-purpose dam provides water for irrigation and hydroelectric power generation while its reservoir, Pantabangan Lake, affords flood control. The reservoir is considered one of the largest in Southeast Asia and also one of the cleanest in the Philippines. Construction on the dam began in 1971 and it was complete in 1977.

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 spillway is a chute-type controlled by three radial gates but equipped with an overflow section as well. The design discharge of the spillway is 4,200 m^3/s (148,322 cu ft/s). The dam's reservoir has a gross capacity of 2,996,000,000 m^3 (2,428,897 acre·ft) and 2,083,000,000 m^3(1,688,716 acre·ft) of that volume is active (or useful) for irrigation and power. The dam sits at the head of an 853 km^2 (329 sq mi) catchment area and its reservoir has a surface area of 69.62 km^2 (27 sq mi) and elevation of 230 m (755 ft) when at its maximum level. The reservoir's life is estimated at 107 years due to silt from denudation. The dam was design to withstand an intensity 10 earthquake.

We also visited the Angat Dam. We are given a lecture about the dam and have a chance to see their spillway and facilities for the hydroelectric power plant.

(FFWS) for Pampanga River Basin was piloted by the government in 1973 in recognition for the need of an operational flood forecasting and warning to help mitigate losses of life and property brought about by annual occurrences of flooding. In 1978, released impoundment water in Angat Dam Flood Forecasting and Warning System in Bulacan resulted to unprecedented flood heights that caused destruction and death downstream of the dam. It was in the light of this sad experience that authorities saw the need for a flood forecasting and warning system in major dam sites. The project is implemented with the National power Corporation (NPC) and the National Irrigation Administration (NIA) as cooperating agencies and the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) as the lead agency.

The Angat River Basin has a total drainage area of 936 sq.km. The upper basin which converts the area from the farthest watershed divide down to Angat Dam is 568 sq.km. These are composed of upper Angat or Maputi sub-basin with a drainage area of 237 sq.km, Matulid sub-basin with drainage of 212 sq.km and Talaguio sub-basin with a drainage area of 119 sq.km.

Angat dam has a normal high water level of 210 meters, according to the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). It has three gates opening a total of 1.5 meters to gradually release water that had accumulated due to incessant rains during typhoons. Angat dam supplies potable water and energy to Metro Manila and nearby areas. Surrounded by lush greens, this place is also ideal for fishing, boating and hunting.



We also had a quick visit to Cong Dadong Dam in Pampanga. It is named after President Diosdado Macapal. The dam which diverts water from Pampanga and Rio Chico Rivers released 1.2 cubic meters per second to canals leading to farms in Arayat, Sta. Ana, San Luis, Candaba, San Simon and Apalit towns. As we visit there we saw a fisher folk catching fish.



We also had a visit in Calumpit Bulacan where we have a lecture about their MDRRMC. MDRRMC are the one who is responsible for the updates and managing their town for the possible floods in their place. We also saw their staff gauge. The green, red and yellow show the level of water. In their staff gauge, we saw the water level of the different typhoons passed in their area where Santi hits the highest mark.

It is important to visit these dams because as an aspiring hydrology we need to know its features and how these dams will operate.

V. CONCLUSION

The following are the conclusions made from the above objectives;

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. For the current meter the discharge is 311.48 cumecs which is way larger, compared to the expected value, and may be due to insufficient data along the piers and other obstructions below a subsection.

b. Float method the discharge is 614.02 cumecs. Since the method was performed twice, the average of the velocities and time should be noted to come up with the discharge.
c. For the slope area method the discharge is 3440.34. This is 11 times the current meter. This was donet using Manning's formula and computation of discharge Q by multiplying the average area with the average velocity.
d. Discharge measurement using ADCP is simple and easy. It was automatically done using the software. The result is 237.668 cumecs which is done three trials.

3. From the above information using the four methods, ADCP is best used because it is simple and easy to use but not advisable for flooding time. The main advantage of the ADCP technology in comparison to the well-established current meter method for water velocity and discharge measurements is the character of data that is obtained. ADCPs provide a continuous data collection throughout the water column and cross section rather than discrete point measurements. The "current profile" outputted by the ADCP associated software is closer to reality than vastly extrapolated cross-section data that can be achieved with current meters. In addition, the ADCP method does not only measure velocity but also the measurement profile.

4. Stage-discharge is relationship between amount of water flowing in a river and stage at any part. Point is usually known as stage-discharge relationship. The rating equation in Arayat, Pampanga is $\mathbf{Q = 0.306(H+7.39)^{3.190}}$. The rating curve of Pampanga River reveals that for each measurement of discharge there is a corresponding measurement of stage. 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.

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