Philippine Atmospheric, Geophysical and Astronomical Services Administration
(PAGASA)
Department of Science and Technology (DOST)

Technical Report in

Stream Gauging II Field Work

at Arayat Station, Pampanga

Submitted by:
Sajulga, Ramjun A.
HTC Trainee
PAGASA, DOST

Submitted to:
Engr. Hilton T. Hernando
Engr. Roy A. Badilla
Engr. Socrates F. Paat Jr.

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1. INTRODUCTION

As part of the curriculum of Hydrologist Training Course Batch 2013 conducted by Philippines Atmospheric, Geophysical and Astronomical Services and Administration (PAGASA), we as trainees are required to undergone fieldwork under the subject Stream Gauging II: Discharge Measurement. An activity that has a duration of 10 days from October 15 to 25 2013 and were executed at the Arayat Station in Pampanga which is under the Pampanga River Flood Forecasting and Warning Center (PRFFWC). Basically the fieldwork was done on the 17th, 18th, 21st, and 22nd day of October, 2013. We apply the four indirect and direct methods of discharge measurement in the field preferably in the cross-sections of the river. These methods are the Slope-Area, Acoustic Doppler Current Profiler (ADCP), Current Meter, and Float. About the center, PRFFWC is a 24/7 operational center since 1973 and it is an office center of the Philippine Atmospheric, Geophysical & Astronomical Services Administration (PAGASA). We also conducted some lectures and fieldtrips/sidetrips during the said activity which is also related to the course. This report will detail the results of the fieldwork which employed the methods of discharge measurements from operation, collection, calculation, and analysis of data from field investigations and on site physical measurements.

2. OBJECTIVES

The trainees should determine the following:

- To be able to measure the discharge of the Pampanga River using different methods (Slope-Area, ADCP, Float , Current Meter)
- To be able to compare and contrast the practical applications of four discharge measurement methods
- To be able to determine the elevation of highest flood mark extent during Typhoon Santi

3. SITE DESCRIPTION:ARAYAT, PAMPANGA

The Pampanga River was the chosen site to work on the different methods of discharge measurement. The actual location of the river cross-sectioning is at Barangay Camba, San Agustin, Arayat with the San Agustin Bridge as the reference landmark considering the existence of the old benchmark at the left bank of the river and the new unmanned telemetered station located at the right bank. Arayat is a first class municipality in the province of Pampanga, Philippines.

The river overtopped its banks due to the rainfall intensity brought by Typhoon Santi that causes flooding to the river channel. Both banks are muddy and contain some shrubs. The streambed of the river comprises small stone rounded by the flow of water; essentially, a cobblestone. The flood left its trace of debris, high floodmark extent/water level marks, loam soils and silt that is visible around the area.

Figure 1. Satellite Image of the site taken from Google Earth.

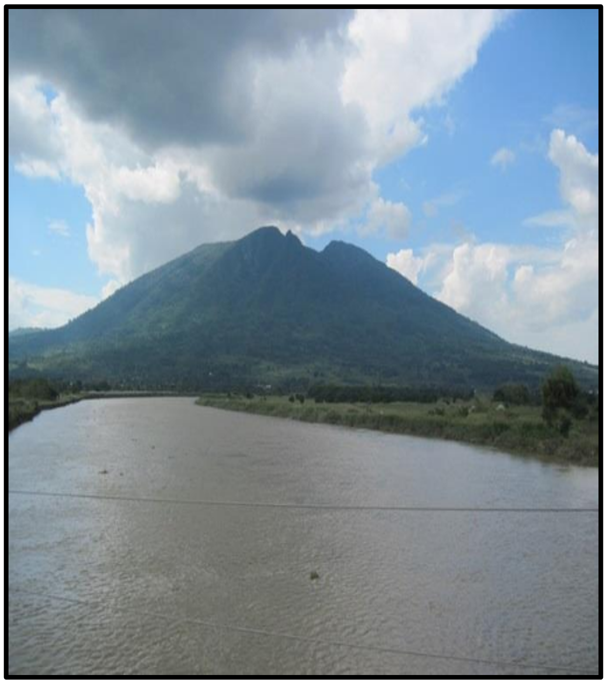


Figure 2. A view of the upstream of Pampanga river at the foot of Mt. Arayat.

Figure 3. A view of the downstream of Pampanga river.

Figure 4. A photo of the new telemetered water level station.

Figure 5. A photo of the old water level station.

4. METHODS FOR DISCHARGE MEASUREMENT

In executing the different types of methods, first the class was divided into four groups. Each group has the assigned method to be undertaken each day and to collect data out of it. Our group did some discussions regarding the methods on how to make some strategies in order for it to be performed in a systematic way. The four methods of discharge measurement were done in the downstream portion of the San Agustin Bridge in Arayat, Pampanga. The details of each method were summarized in the following sections below.

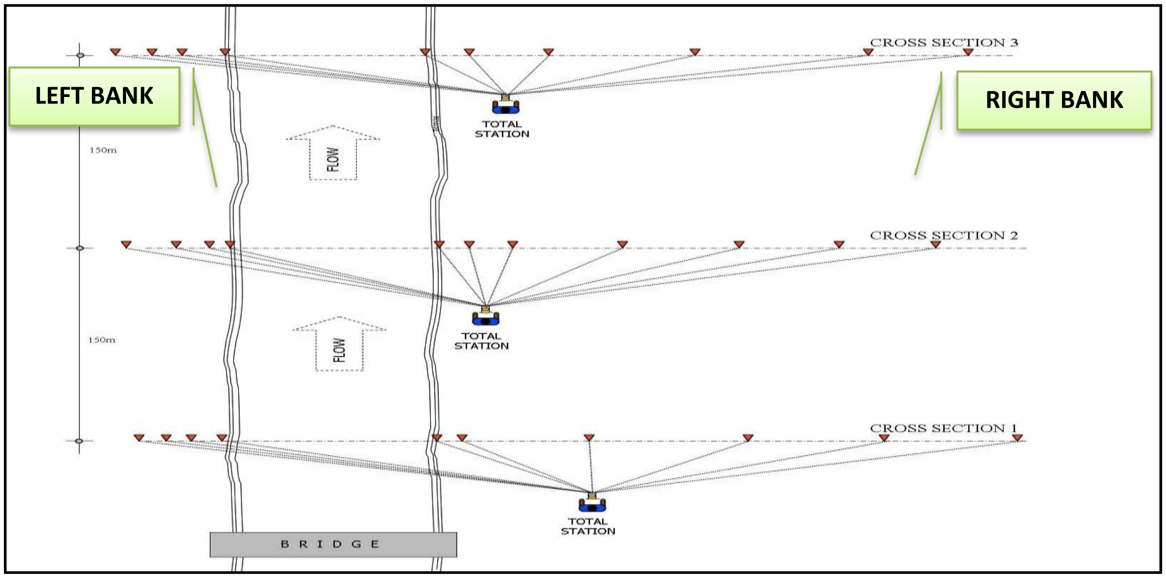
4.1. Slope-Area Method

This method was the first method we performed in the field. We are given advice by our instructor to determine the highest floodmark in every cross-section.

4.1.1. Cross-section survey

A surveying instrument which is the total station was used to conduct a river-cross section survey. The following are the procedures that our group being performed:

- We locate the benchmark and get its elevation, horizontal distance, and the horizontal angle at the old water level station at the left bank of the channel upstream as basis for our reference point.
- Then we transferred the benchmark to the right bank of the river. We measure 53m from the bridge to our first cross-section using a range finder. This distance will also be the basis for the float method first cross-section.
- From the first cross-section, we measure again 150m from the first cross-section to the second cross-section and then another 150m for the third cross-section with a total length of 300m.
- At the river, echo-sounder was used to obtain the surface water and river bed depth for all the three cross-sections.



4.1.2 Issues and difficulties encountered

Some of the issues and difficulties had been encountered by the group during the survey, some of which are the inherent limitations of the Slope-Area method. Those are:

1. Identification of flood marks – The floodmarks are not easy to find and are often elevated above actual water level. At the right bank, we were able to find the floodmarks but we were forced to do estimation because it's hard to access the area due to some hindrances like the fences (barbed wire) and tall grasses. At the left bank, we need to climb the banks in order to identify the highest floodmark extent which is so steep, muddy, and full of shrubs.
2. Tedious nature of the survey work – This method was really the most time consuming knowing that we are the first group to perform and we still don't know some of the procedures. The group had to survey the area and measures 300m along the river downstream, walking on muddy ground, and climbing the banks.
3. Stability of the boat used during the river survey – We used boat to get the depth measurement and it was hard to maintain a straight line of depth measurement across the river because of the flow. There was no tagline used at the time to guide the boat because the tagline or the rope to be used wasn't good enough to reach the other bank.

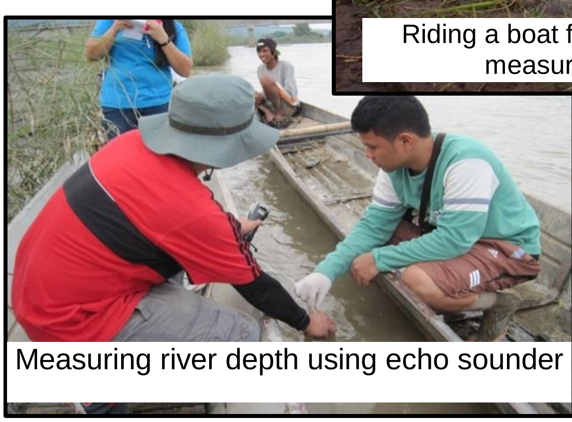
4. Equipment issues - For a moment during the survey, the total station suddenly went off. There was a problem with the equipment's power supply but it was fortunate that the group, together with our mentor at the time, was able to find a remedy. The range finder's readings were also inaccurate and the device cannot read the distance toward the opposite bank.
5. Terrain – Since the site was fresh from rainfall brought by Typhoon Santi, the ground was so muddy on the first day of measurements. The group had a difficulty finding a stable area for the equipment and the rod crystal to be positioned in order to measure the elevation of the ground, especially along the banks.

4.1.3. Photos during S-A method


Floodmark


Standing in a muddy ground


Riding a boat for river depth measurement


Measuring river depth using echo sounder


Sighting a distance using total station

4.2. Acoustic Doppler Current Profiler (ADCP)

This method was the second method we had been performed. This kind of method was direct and automatic in measuring discharge, in the sense that you only have to guide the buoy or the equipment across the river and it will automatically sends data to the computer based on the area read by it. ADCP measures the water current velocities over a depth range using the Doppler effect of sound waves scattered back from particles within the water column. The ADCPs use the traveling time of the sound to determine the position of the moving particles. It is typically used to measure streamflow. Along with measuring water velocities, they can measure depths and allows them to measure discharge while moving across a channel.

Things to be needed:

In our group, the following are the things that we had been used during this method:

- ADCP itself
- Boat
- Tape measure
- One-way radio telephone
- Life jacket (for safety purpose)

4.2.1. <u>Procedures and Set-up</u>

The procedures that the group being performed are as follows:

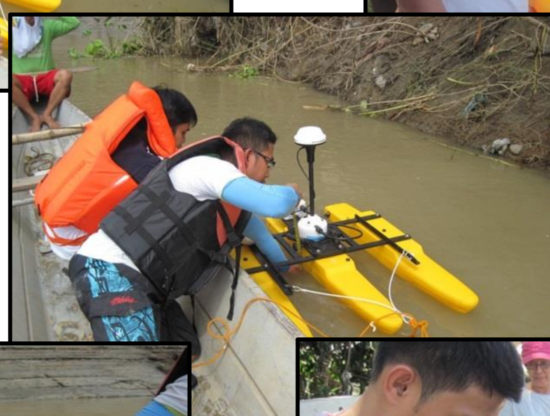
- We assemble the equipment by putting the parts on the yellow-colored plastic vessel such as fitting the antenna, inserting the battery, sensor, transmitter, data logger and computer interface connections.
- Before taking the measurement the instrument was calibrated by doing the three axes – the yaw, roll, and pitch within two minutes until the software will display on the computer “passed calibration”. Measurement starts when the calibration is done.
- The measurement was done 50m from the bridge downstream. The equipment was mounted to a boat that allows them to traverse from one bank to the other side. The flow of the river was still strong for as the boat had

difficulties guiding the ADCP to transect across the river perpendicular to the flow. It is important that the operator of the computer and the person riding the boat will have a constant communication.

- ➢ The distance from the initial point to the water edge will be measured either in the left or right bank of the river, also the gauge height should be noted in order for the software to start.
- ➢ When the equipment reaches the other side of the river, it is required to measure the end point of the equipment to the water edge.

4.2.2. Photos in field





4.3. Current Meter (on the bridge)

The third method we had been performed. The process was carried out on top of bridge. Our measurement started from the water edge left bank going to the right bank water edge. The discharge can be computed by the summation of all partial discharges in each segments or partial areas. This was done so that the partial discharges may not exceed 10 percent of the total.

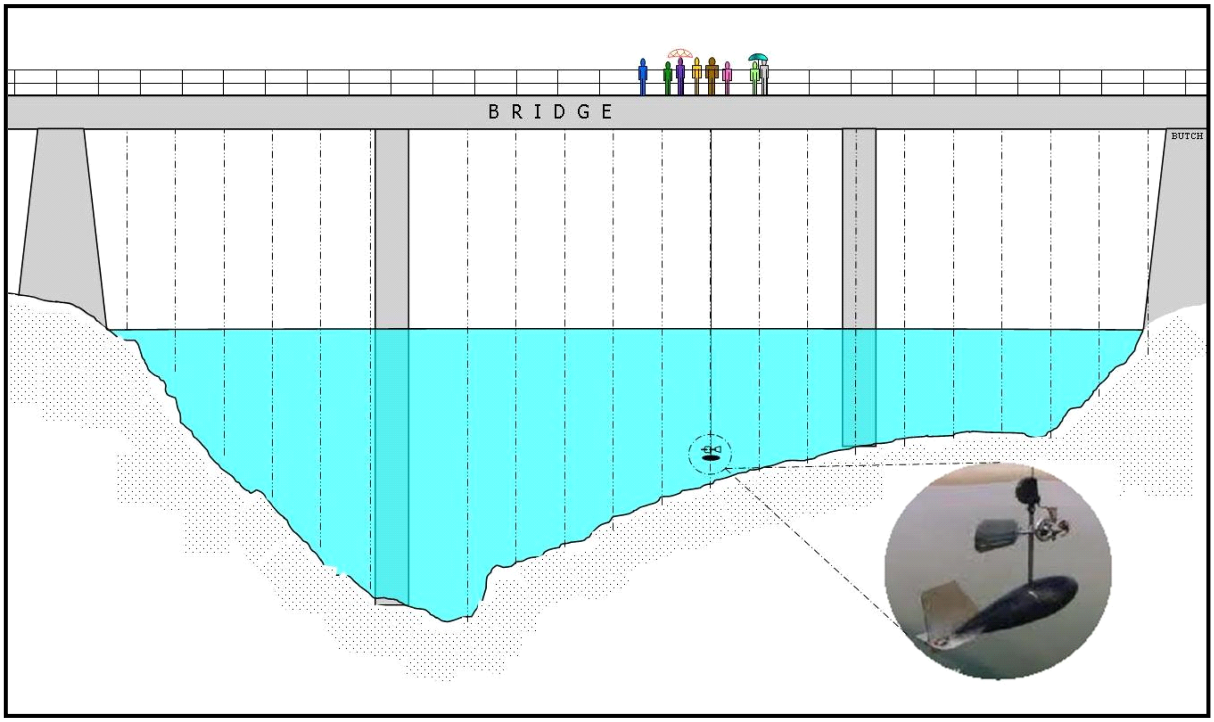
Things to be needed:

- Pryce AA current meter
- Sounding reel (20m)
- Columbus weight
- Beeper
- Stopwatch
- Angle bar
- Notebook
- Protractor

4.3.1. Procedures: Set-up, Obtaining the segments, Velocity Measurement

The following are procedures we had been through during this method:

- Assembling the Pryce AA meter to the sounding reel, tighten the knots, put the Columbus, and then connect the beeper.
- Dividing the width of the river into 24 segments (sometimes referred to as partial areas or panels) with an interval of 5m across the bridge from the banks and switching to 3m near the pier as approaching to middle portions of the river.
- The sounding reel was then set-up. The Columbus weight attached to a hanger bar and to the cable from the sounding reel.
- The current meter were lowered to the surface of the water and take the reading. After, set the indicator to zero and then lowered again the current meter to 0.2 and 0.8 depth and take the reading.
- Depths at each point were then measured using an echo sounder prior to the actual measurement of velocities.



A view of the operation using current meter method

4.3.2. **Photos in field**

4.4. Float Method

The basic idea is to measure the time that it takes the object to float a specified distance downstream. The bamboo was designed as a floater to represent the water surface velocity measurement in time. Float method is essential or suggested during flooding time. One of the limitations of this method is that the float traverses to other side at/during low flow.

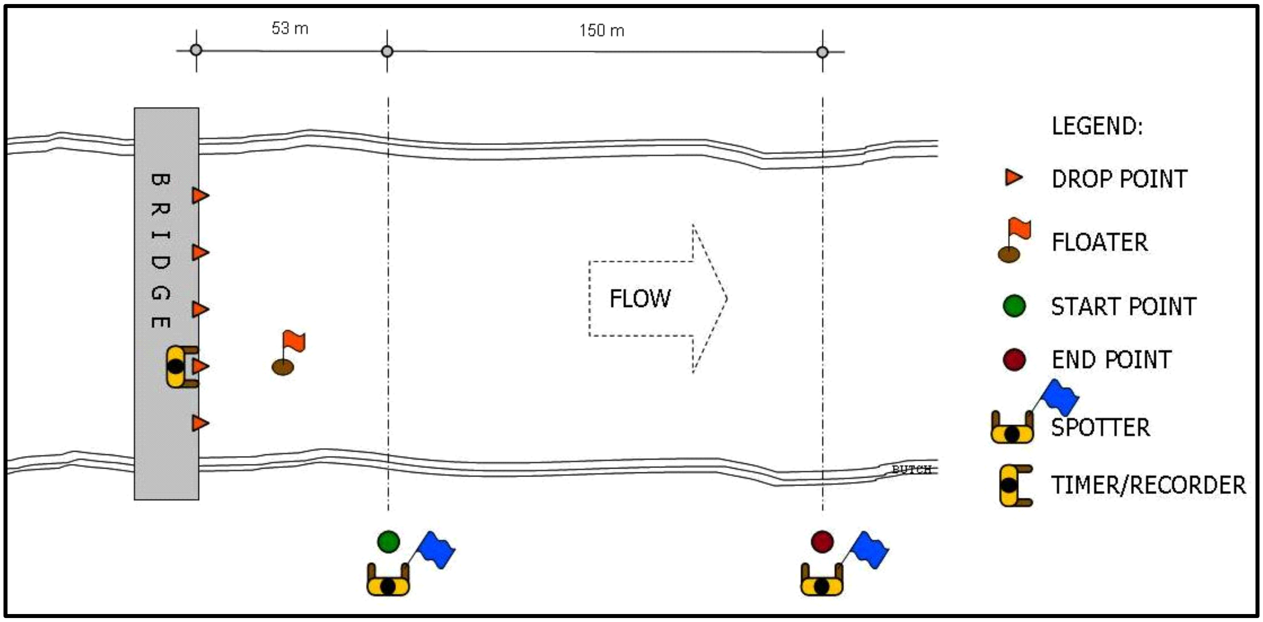
Things to be needed:

The following are the things we used during this method:

- 10 Bamboos as a floater
- Stopwatch
- Notebook

4.4.1. Procedures of measurements in transit time

- The width of the bridge was divided into 5 segments/sections with corresponding distances.
- The cross-sections will be the same as the slope-area. The distance of the first section from the bridge was 53m and 150m from the first section to the second section.
- Our group was divided into two teams, the 1st team will be assigned to drop the floats and the second team will be assigned as a timer as it passes the sections.
- At first trial of measurement, the 5 bamboo floater was dropped at the points being divided from right bank to left bank
- The second set of measurements was done from the left bank towards the right bank. Unlike the first pass, however, the floater did not resurface on the 1st and 2nd drop while floater did not move at the 5th drop. It was during this time frame that the water level at the arayat station started to significantly reduce due to the closure of the nearby dam (cong dadong dam). Due to the circumstances, readings on the 2nd pass were disregarded during the computations.



A view of the operation of Float Method

4.4.2. <u>Photos in field</u>

5. RESULTS AND DISCUSSION

The following tables, graphs, and illustrations are the results of the activity from the four different discharge measurement methods and were summarized below.

5.1. Slope-Area Method

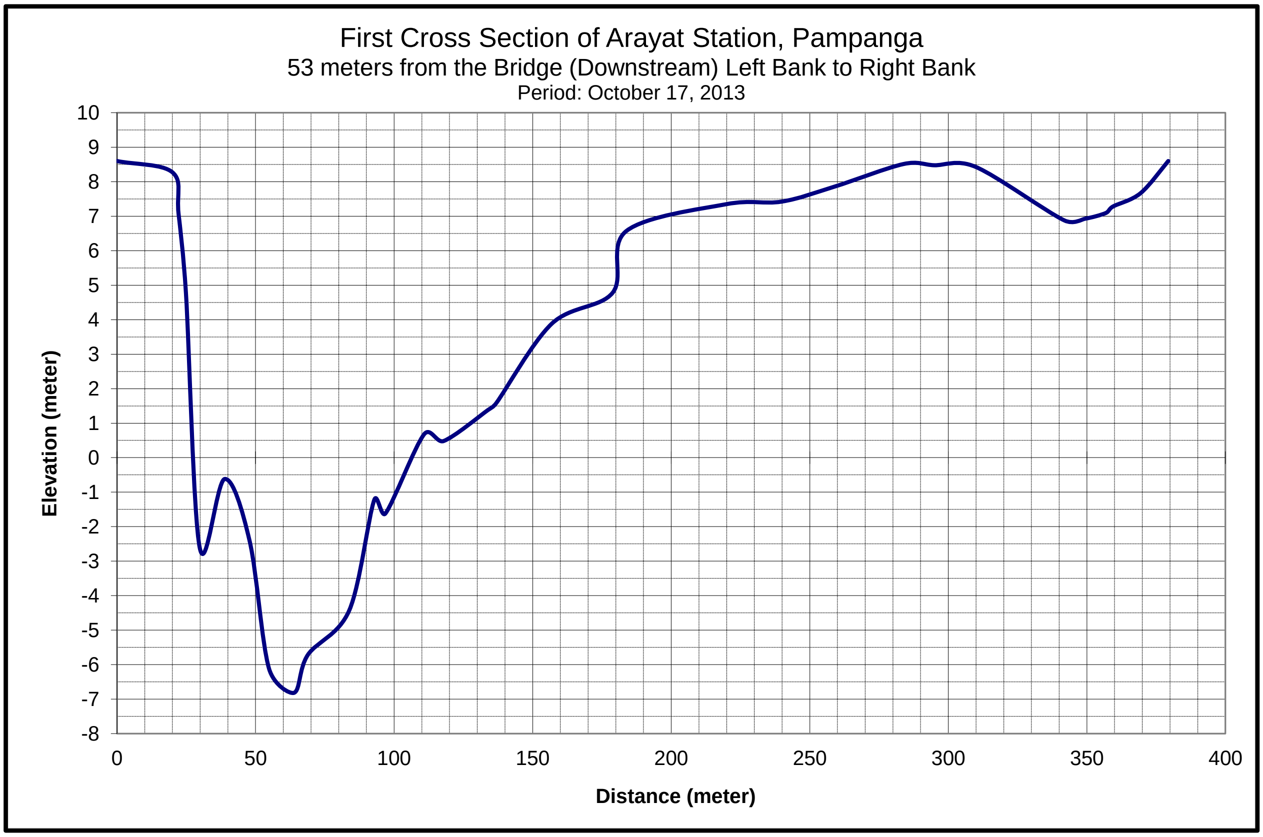
The tables below show the summary of the survey that was done for each cross section, going from left bank to right bank:

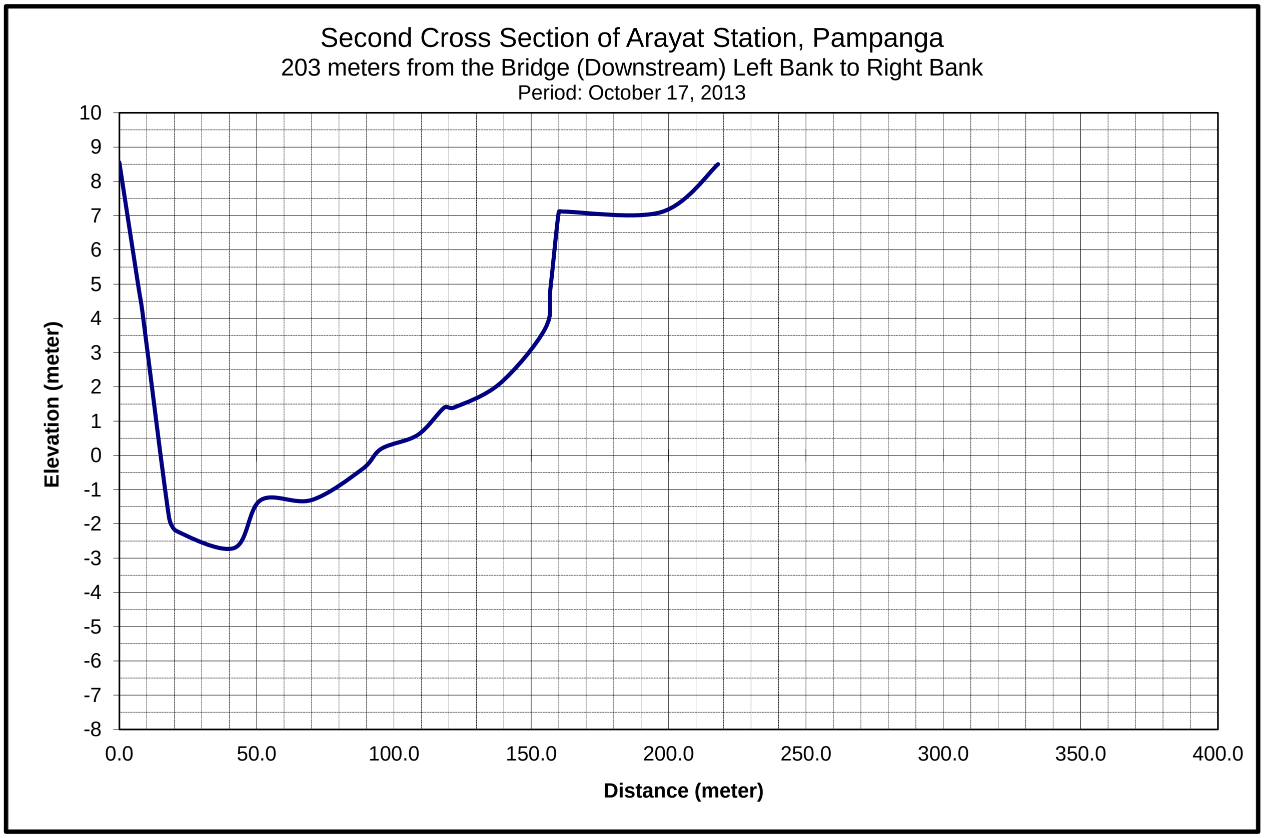
POINT	FIRST CROSS-SECTION			ELEVATION
	DISTANCE			
	ACTUAL	CORRECTED	ACCUMULATED CORRECTED	
P1	0	0	0	8.6
P2	20	20.00	20	8.272
P3	2.2	2.20	22.2	7.072
P4	2.66	2.66	24.86	4.782
P5	5	5.00	29.86	-2.618
P6	9	9.00	38.86	-0.618
P7	9	9.00	47.86	-2.418
P8	7	7.00	54.86	-6.118
P9	9	9.00	63.86	-6.818
P10	5	5.00	68.86	-5.718
P11	15	15.00	83.86	-4.418
P12	9	9.00	92.86	-1.218
P13	4	4.00	96.86	-1.618
P14	14	14.00	110.86	0.682
P15	7	7.00	117.86	0.482
P16	16	16.00	133.86	1.382
P17	3	3.00	136.86	1.582
P18	20	20.00	156.86	3.882
P19	22	22.00	178.86	4.782
P20	5	5.00	183.86	6.575
P21	36	36.00	219.86	7.349
P22	20	20.00	239.86	7.424
P23	19	19.00	258.86	7.857
P24	25	25.00	283.86	8.514
P25	11	11.00	294.86	8.478
P26	15	15.00	309.86	8.431
P27	32	32.00	341.86	6.879
P28	7.5	7.50	349.36	6.928
P29	7.5	7.50	356.86	7.094
P30	2.5	2.50	359.36	7.279
P31	10	10.00	369.36	7.667
P32	10	10.00	379.36	8.6

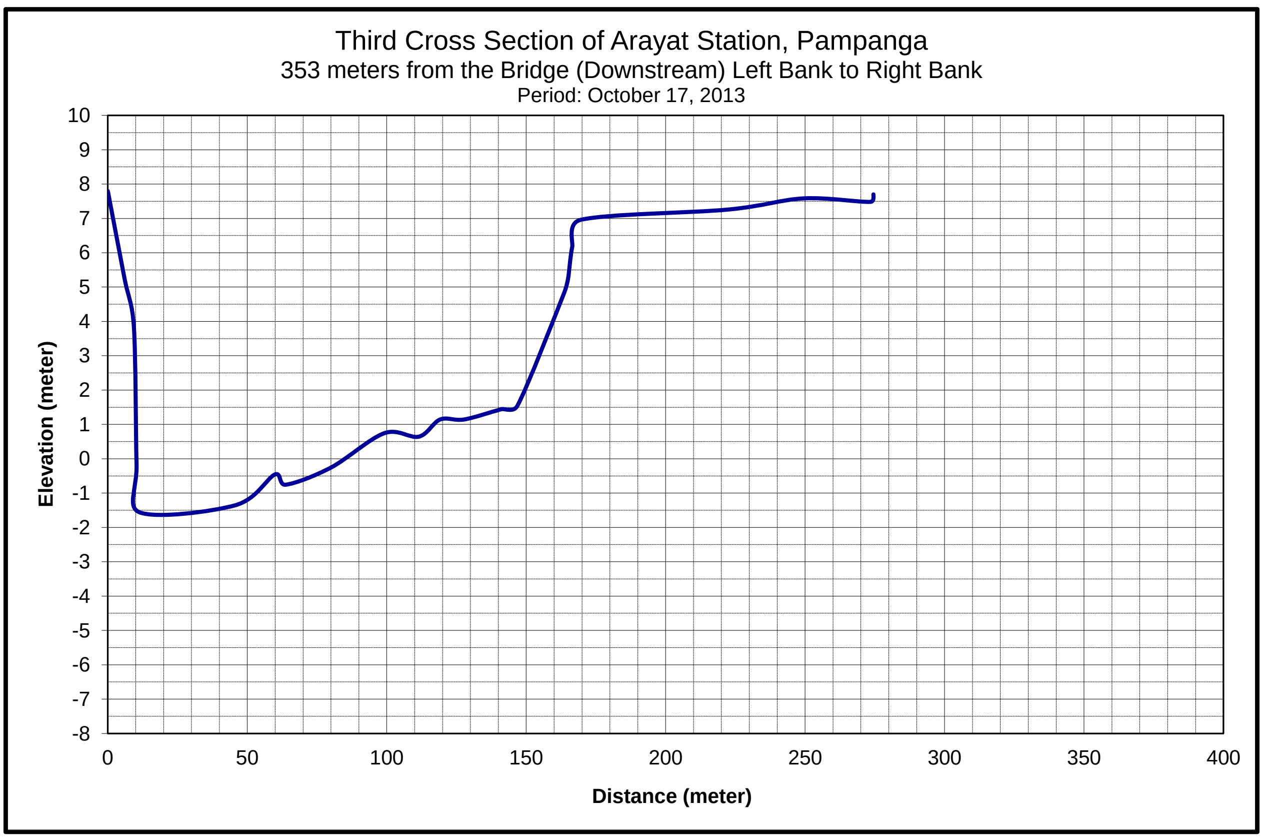
POINT	SECOND CROSS-SECTION			ELEVATION
	DISTANCE			
	ACTUAL	CORRECTED	ACCUMULATED CORRECTED	
P1	0	0	0.0	8.552
P2	7.00	7.00	7.0	4.895
P3	1.41	1.41	8.4	4.185
P4	9.67	9.67	18.1	-1.805
P5	2.64	2.64	20.7	-2.205
P6	21.10	21.10	41.8	-2.705
P7	9.67	9.67	51.5	-1.305
P8	18.46	18.46	70.0	-1.305
P9	18.46	18.46	88.4	-0.405
P10	7.03	7.03	95.5	0.195
P11	13.19	13.19	108.6	0.595
P12	9.67	9.67	118.3	1.395
P13	3.52	3.52	121.8	1.395
P14	16.71	16.71	138.5	2.095
P15	16.48	16.48	155.0	3.695
P16	1.99	1.99	157.0	4.895
P17	6.00	3.00	160.0	7.103
P18	6.10	1.50	161.5	7.117
P19	36.00	36.00	197.5	7.106
P20	25.00	20.50	218.0	8.5

POINT	THIRD CROSS-SECTION			ELEVATION
	HORIZONTAL DISTANCE			
	ACTUAL	CORRECTED	ACCUMULATED CORRECTED	
P1	0	0	0	7.797
P2	11	6.00	6	5.244
P3	3.34	3.34	9.34	3.844
P4	0.957	0.96	10.297	-0.156
P5	0.955	0.96	11.252	-1.556
P6	34.378	34.38	45.63	-1.356
P7	14.32	14.32	59.95	-0.456
P8	3.82	3.82	63.77	-0.756
P9	16.24	16.24	80.01	-0.256
P10	19.098	19.10	99.108	0.744
P11	12.412	12.41	111.52	0.644
P12	7.642	7.64	119.162	1.144
P13	8.595	8.60	127.757	1.144
P14	13.369	13.37	141.126	1.444
P15	5.73	5.73	146.856	1.544
P16	16.712	16.71	163.568	4.824
P17	1.432	1.43	165	5.244
P18	1.5	1.50	166.5	6.166
P19	3	3.00	169.5	6.958
P20	53.5	53.00	222.5	7.259
P21	30.5	27.00	249.5	7.584
P22	24.5	24.00	273.5	7.483
P23	1	1.00	274.5	7.7

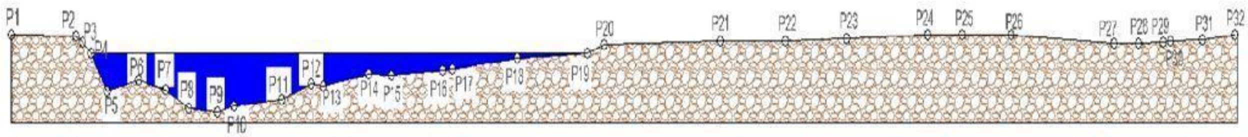
The illustrations below are the cross sections from left bank to right bank with values for elevation referenced to Mean Sea Level for Slope-Area Method:



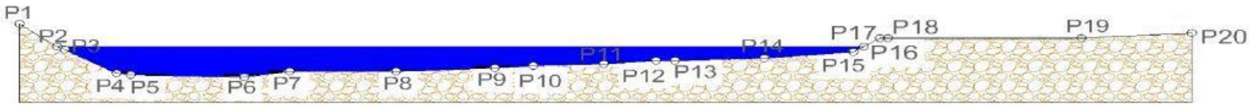

Second Cross Section of Arayat Station, Pampanga
203 meters from the Bridge (Downstream) Left Bank to Right Bank
Period: October 17, 2013
Elevation (meter)
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
Distance (meter)


Third Cross Section of Arayat Station, Pampanga
353 meters from the Bridge (Downstream) Left Bank to Right Bank
Period: October 17, 2013
Elevation (meter)
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0
50
100
150
200
250
300
350
400
Distance (meter)

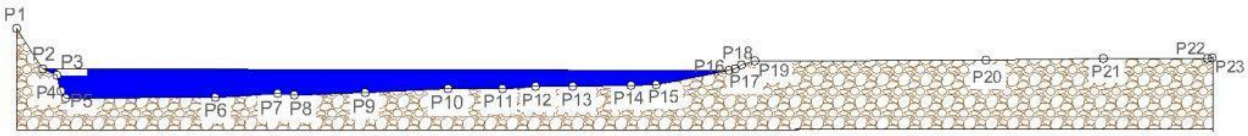
The illustrations below show the same cross sections plotted out in AutoCAD[1]:



FIRST CROSS SECTION



SECOND CROSS SECTION



THIRD CROSS SECTION

5.1.1. Computation of Discharge

For easy computations, an excel suite use for automatic discharge computation by slope-area method was provided by our instructor Mr. Hilton T. Hernando. The data gathered for the three cross-sections can be entered directly. The estimated discharge at the time of the flood by slope area method was **3983.73** cubic meters per second. The result was presented in image form and as follows:

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

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

Station:	*Arayat*	River:	*Pampanga River*
Flood Date:	*13-Oct-13*	Drainage Area:	*6,487*
Gauge Height:	*8.78*	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	379.36	1623.42	8.272	8.6	8.436	4.279	0.04	4.19	106006.9	4.5E+08	1	0.379	tranquil
2	218.00	1355.39	8.552	8.5	8.526	6.217	0.04	6.10	113808.7	8E+08	1	0.377	tranquil
3	274.50	1221.98	7.797	7.7	7.7485	4.452	0.04	4.36	81973.56	3.7E+08	1	0.494	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	150	-0.09	0	contracting	0.931448	good	1489.403	x	x
2-3	150	0.7775	0	contracting	1.388359	good	1288.681	5881.839	4.564
1-2-3	300	0.6875	0	contracting	1.293184	good	1400.260	**3983.727**	2.845

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	x	0.307229	0.440754	-0.13353	-0.22353	-0.00149	x	109838.6	x
2-3	5881.839	0.440754	0.542249	-0.10149	0.676006	0.004507	0.067132	96588.32	6484.168

Q_{1-2-3} = **3983.73** **cumecs**

Discharge

Rem:

Slope-Area Cross-Section Computation							
Station:	*Arayat*			Survey Date:		*17-Oct-13*	
River:	*Pampanga*				Gage Ht.=	*5.31*	meters
Cross-Section number ONE (1)							
Station	**Distance**	**Elevation**	**Water Sfc. elev.**	**Depth**	**Mean Depth**	**Area**	**Wetted Perimeter**
0		8.6	8.6	0			
20	20	8.272	8.6	0.328	0.164	3.28	20.00269
22.2	2.2	7.072	8.6	1.528	0.928	2.0416	2.505993
24.86	2.66	4.782	8.6	3.818	2.673	7.11018	3.509943
29.86	5	-2.618	8.6	11.218	7.518	37.59	8.930845
38.86	9	-0.618	8.6	9.218	10.218	91.962	9.219544
47.86	9	-2.418	8.6	11.018	10.118	91.062	9.178235
54.86	7	-6.118	8.6	14.718	12.868	90.076	7.917702
63.86	9	-6.818	8.6	15.418	15.068	135.612	9.027181
68.86	5	-5.718	8.6	14.318	14.868	74.34	5.11957
83.86	15	-4.418	8.6	13.018	13.668	205.02	15.05623
92.86	9	-1.218	8.6	9.818	11.418	102.762	9.551963
96.86	4	-1.618	8.6	10.218	10.018	40.072	4.01995
110.86	14	0.682	8.6	7.918	9.068	126.952	14.18767
117.86	7	0.482	8.6	8.118	8.018	56.126	7.002857
133.86	16	1.382	8.6	7.218	7.668	122.688	16.02529
136.86	3	1.582	8.6	7.018	7.118	21.354	3.006659
156.86	20	3.882	8.6	4.718	5.868	117.36	20.13182
178.86	22	4.782	8.6	3.818	4.268	93.896	22.0184
183.86	5	6.575	8.6	2.025	2.9215	14.6075	5.311765
219.86	36	7.349	8.6	1.251	1.638	58.968	36.00832
239.86	20	7.424	8.6	1.176	1.2135	24.27	20.00014
258.86	19	7.857	8.6	0.743	0.9595	18.2305	19.00493
283.86	25	8.514	8.6	0.086	0.4145	10.3625	25.00863
294.86	11	8.478	8.6	0.122	0.104	1.144	11.00006
309.86	15	8.431	8.6	0.169	0.1455	2.1825	15.00007
341.86	32	6.879	8.6	1.721	0.945	30.24	32.03761
349.36	7.5	6.928	8.6	1.672	1.6965	12.72375	7.50016
356.86	7.5	7.094	8.6	1.506	1.589	11.9175	7.501837
359.36	2.5	7.279	8.6	1.321	1.4135	3.53375	2.506836
369.36	10	7.667	8.6	0.933	1.127	11.27	10.00752
379.36	10	8.6	8.6	0	0.4665	4.665	10.04343
Total Width =		379.36	meters	Hydraulic Radius(r) =		4.19	meters
Total Area =		1623.42	meters^2	Mean Section Depth =		4.279362	meters
Wetted Perimeter(P) =		387.344	meters				

Slope-Area Cross-Section Computation							
Station:	*Arayat*			Survey Date:		*17-Oct-13*	
River:	*Pampanga*				Gage ht.=	*5.31*	meters
Cross-Section number TWO (2)							
Station	**Distance**	**Elevation**	**Water Sfc. elev.**	**Depth**	**Mean Depth**	**Area**	**Wetted Perimeter**
0.0		8.552	8.5	-0.052			
7.0	7	4.895	8.5	3.605	1.7765	12.4355	7.897699
8.4	1.4068	4.185	8.5	4.315	3.96	5.570928	1.575813
18.1	9.6718	-1.805	8.5	10.305	7.31	70.70086	11.37646
20.7	2.6374	-2.205	8.5	10.705	10.505	27.70589	2.66756
41.8	21.104	-2.705	8.5	11.205	10.955	231.1943	21.10992
51.5	9.670166	-1.305	8.5	9.805	10.505	101.5851	9.770983
70.0	18.4643	-1.305	8.5	9.805	9.805	181.0424	18.4643
88.4	18.4643	-0.405	8.5	8.905	9.355	172.7335	18.48622
95.5	7.034018	0.195	8.5	8.305	8.605	60.52773	7.059562
108.6	13.18878	0.595	8.5	7.905	8.105	106.8951	13.19485
118.3	9.671775	1.395	8.5	7.105	7.505	72.58667	9.704805
121.8	3.517009	1.395	8.5	7.105	7.105	24.98835	3.517009
138.5	16.70579	2.095	8.5	6.405	6.755	112.8476	16.72045
155.0	16.47719	3.695	8.5	4.805	5.605	92.35464	16.55469
157.0	1.98711	4.895	8.5	3.605	4.205	8.355798	2.321337
160.0	3	7.103	8.5	1.397	2.501	7.503	3.724952
161.5	1.5	7.117	8.5	1.383	1.39	2.085	1.500065
197.5	36	7.106	8.5	1.394	1.3885	49.986	36
218.0	20.49956	8.5	8.5	0	0.697	14.28819	20.5469
Total Width =		218.00	meters	Hydraulic Radius(r) =		6.10	meters
Total Area =		1355.39	meters^2	Mean Section Depth =		6.21737	meters
Wetted Perimeter(P) =		222.194	meters				

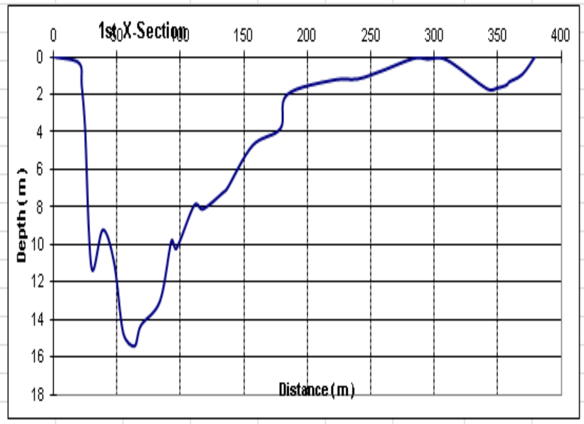
Slope-Area Cross-Section Computation

Station:	Arayat			Survey Date:	17-Oct-13		
River:	Pampanga			Gage ht.=	5.31	meters	
Cross-Section number THREE (3)							
Station	Distance	Elevation	Water Sfc. elev.	Depth	Mean Depth	Area	Wetted Perimeter
0.0		7.797	7.7	-0.097			
6.0	6	5.244	7.7	2.456	1.1795	7.077	6.520568
9.3	3.34	3.844	7.7	3.856	3.156	10.54104	3.621547
10.3	0.957	-0.156	7.7	7.856	5.856	5.604192	4.112888
11.3	0.955	-1.556	7.7	9.256	8.556	8.17098	1.694705
45.6	34.378	-1.356	7.7	9.056	9.156	314.764968	34.37858
60.0	14.32	-0.456	7.7	8.156	8.606	123.23792	14.34825
63.8	3.82	-0.756	7.7	8.456	8.306	31.72892	3.831762
80.0	16.24	-0.256	7.7	7.956	8.206	133.26544	16.2477
99.1	19.098	0.744	7.7	6.956	7.456	142.394688	19.12416
111.5	12.412	0.644	7.7	7.056	7.006	86.958472	12.4124
119.2	7.642	1.144	7.7	6.556	6.806	52.011452	7.65834
127.8	8.595	1.144	7.7	6.556	6.556	56.34882	8.595
141.1	13.369	1.444	7.7	6.256	6.406	85.641814	13.37237
146.9	5.73	1.544	7.7	6.156	6.206	35.56038	5.730873
163.6	16.712	4.824	7.7	2.876	4.516	75.471392	17.03084
165.0	1.432	5.244	7.7	2.456	2.666	3.817712	1.492322
166.5	1.5	6.166	7.7	1.534	1.995	2.9925	1.760706
169.5	3	6.958	7.7	0.742	1.138	3.414	3.102783
222.5	53	7.259	7.7	0.441	0.5915	31.3495	53.00085
249.5	27	7.584	7.7	0.116	0.2785	7.5195	27.00196
273.5	24	7.483	7.7	0.217	0.1665	3.996	24.00021
274.5	1	7.7	7.7	0	0.1085	0.1085	1.023274
Total Width =	274.50	meters	Hydraulic Radius(r) =		4.36	meters	
Total Area =	1221.98	meters²	Mean Section Depth =		4.451640036	meters	
Wetted Perimeter(P) =	280.062	meters					

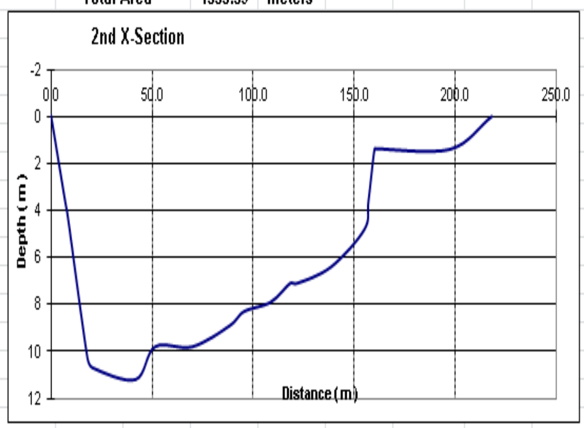
Station: *Arayat* Date: *17-Oct-13*

River: *Pampanga* Gage Ht. 5.31 meters

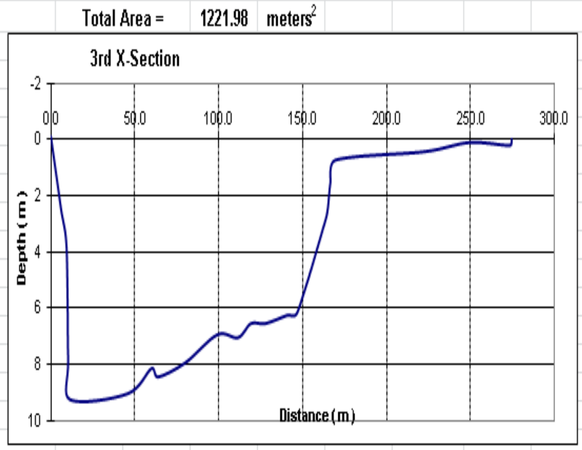
Total Area = 1623.42 meters²



Total Area = 1355.39 meters²

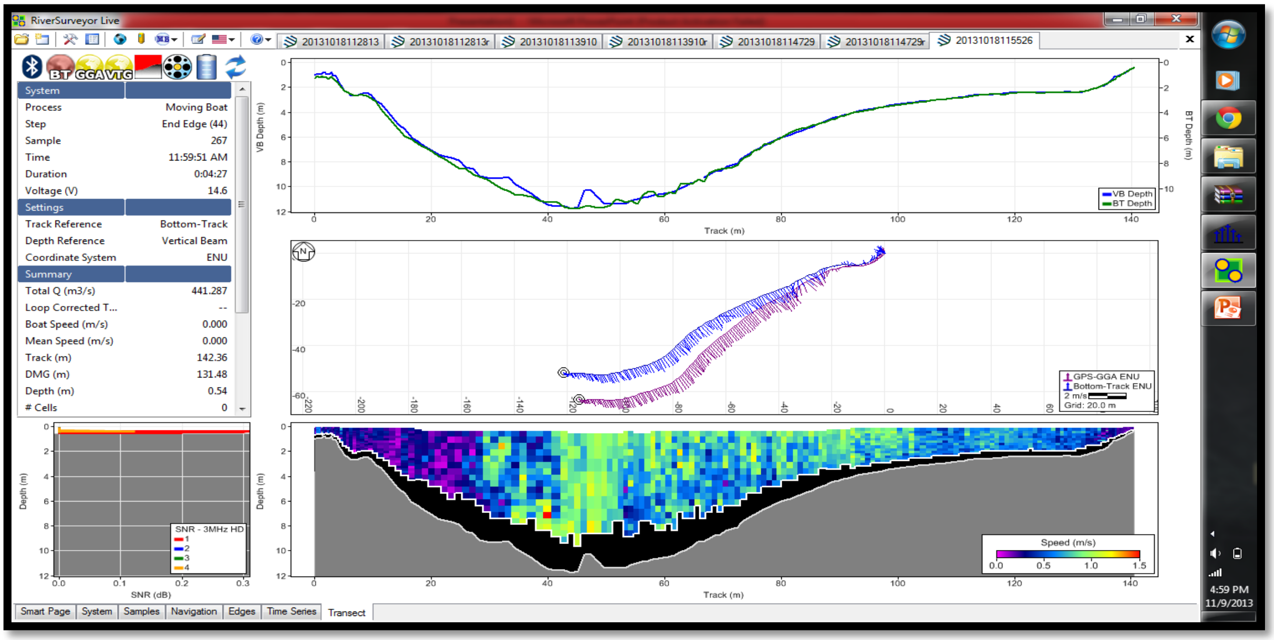


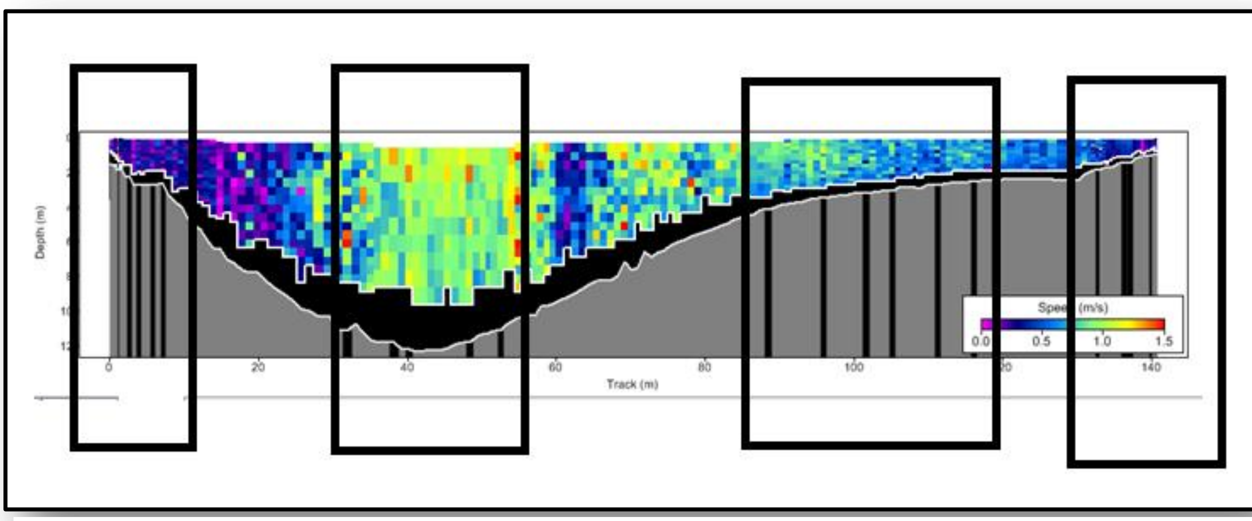
Total Area = 1221.98 meters²



5.2. <u>ADCP</u>

Base on the data receive by the computer from the equipment, the results were represented graphically in the computer. The discharge measured at this transect was <u>441.287 cubic meters per second</u>, at gauge height equal to 4.65 m.



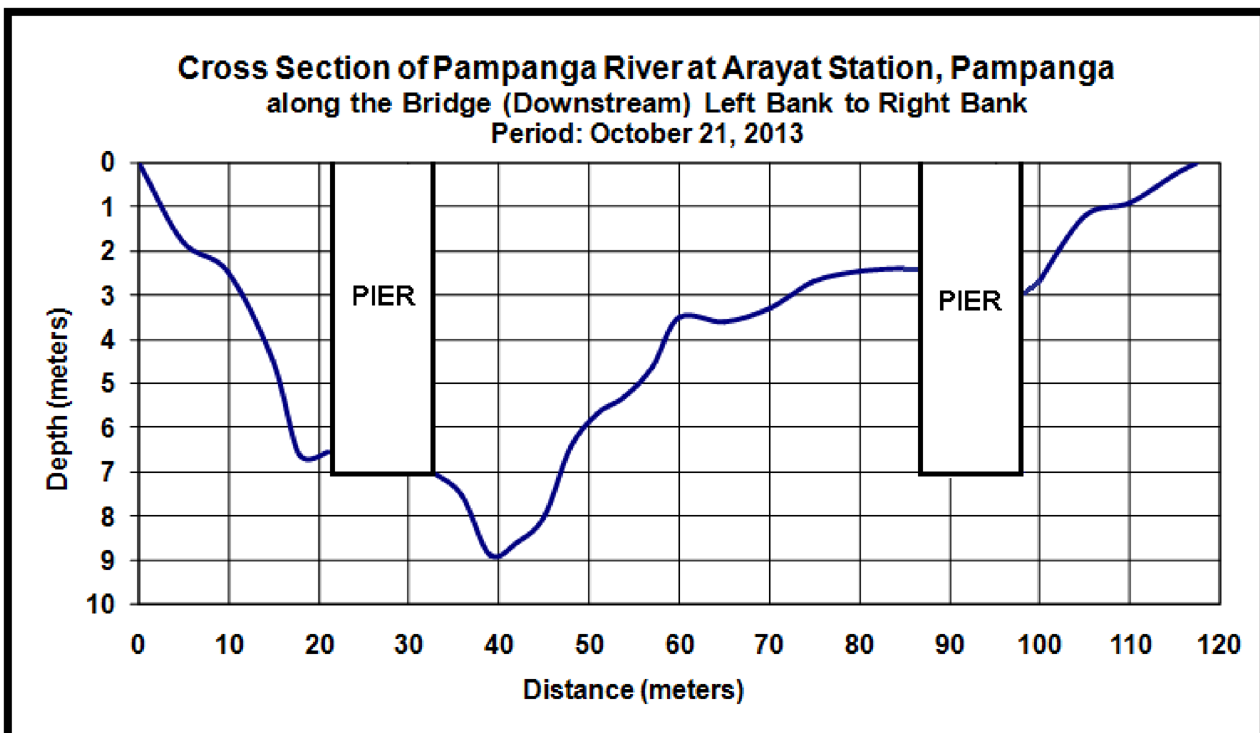


A view of the first transect. The vertical bars below the streambed represent the invalid ensembles which is the result from invalid bottom tracking.

5.3. Current Meter

The excel suite provided by our instructor, Mr Hilton T. Hernando made the calculations faster for current meter discharge. The summary of all data and calculations are shown below.

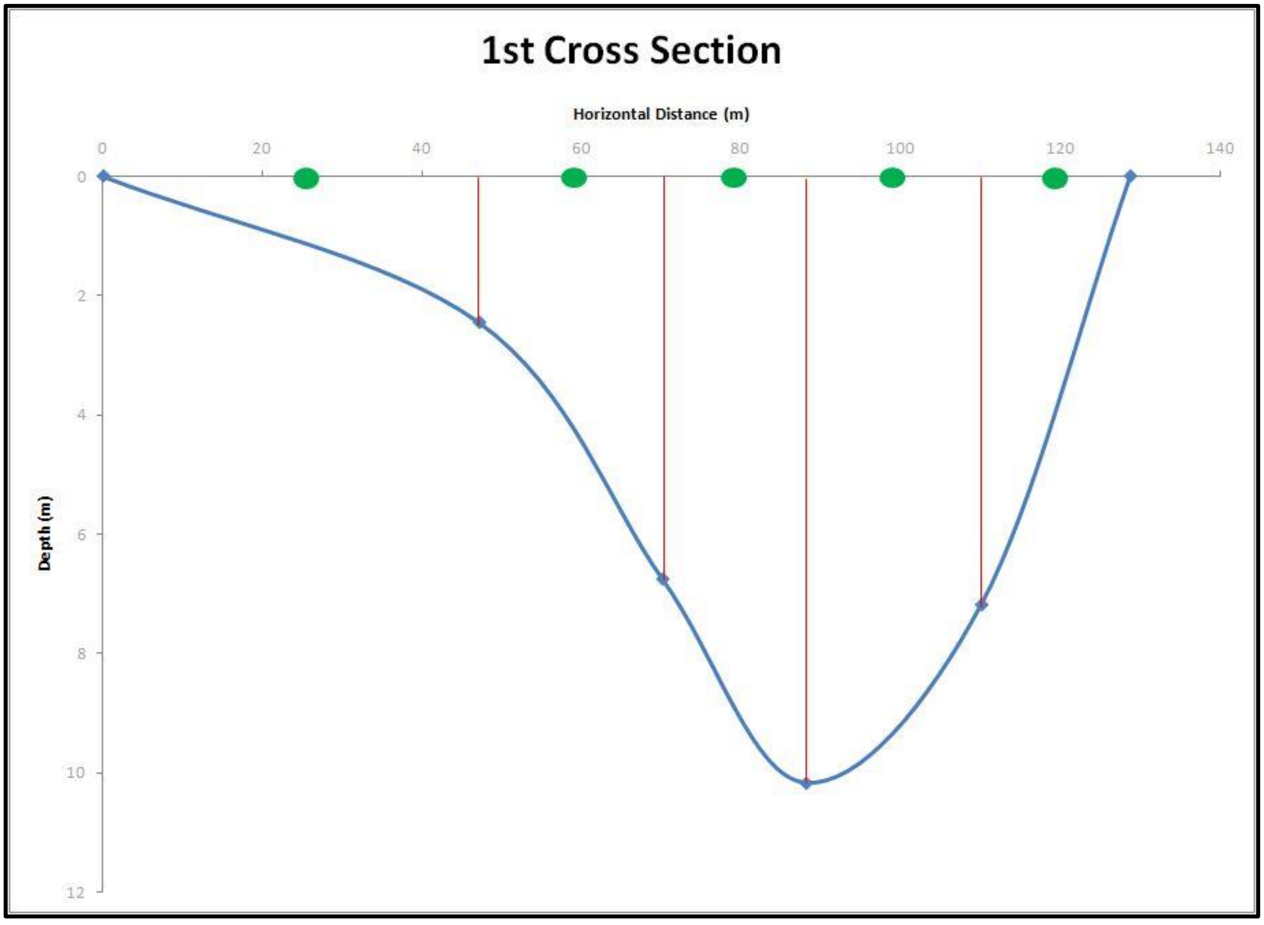
Computation of Mean Gage Height by Q weighting Process						
Station :	ARAYAT STATION			Date :	October 21, 2013	
River :	PAMPANGA RIVER					
DM # :	03			M.G.H.	3.12	meters
Time (0000)	Gage Height Reading	Ave. Gage Height		Q_{total} ending at Time	Ave. G.H. * Q	Remarks
1115	3.15					
1200	3.12	3.135		65.93	206.69	
1300	3.12	3.120		101.93	318.01	
1400	3.11	3.115		97.44	303.52	
1442	3.08	3.095		28.12	87.04	
		x			x	
		x			x	
		x			x	
		x			x	
		x			x	
		x			x	
		x			x	
		x			x	
		x			x	
			Totals =	293.42	915.26	
		Mean Gage Height =		3.12	meters	



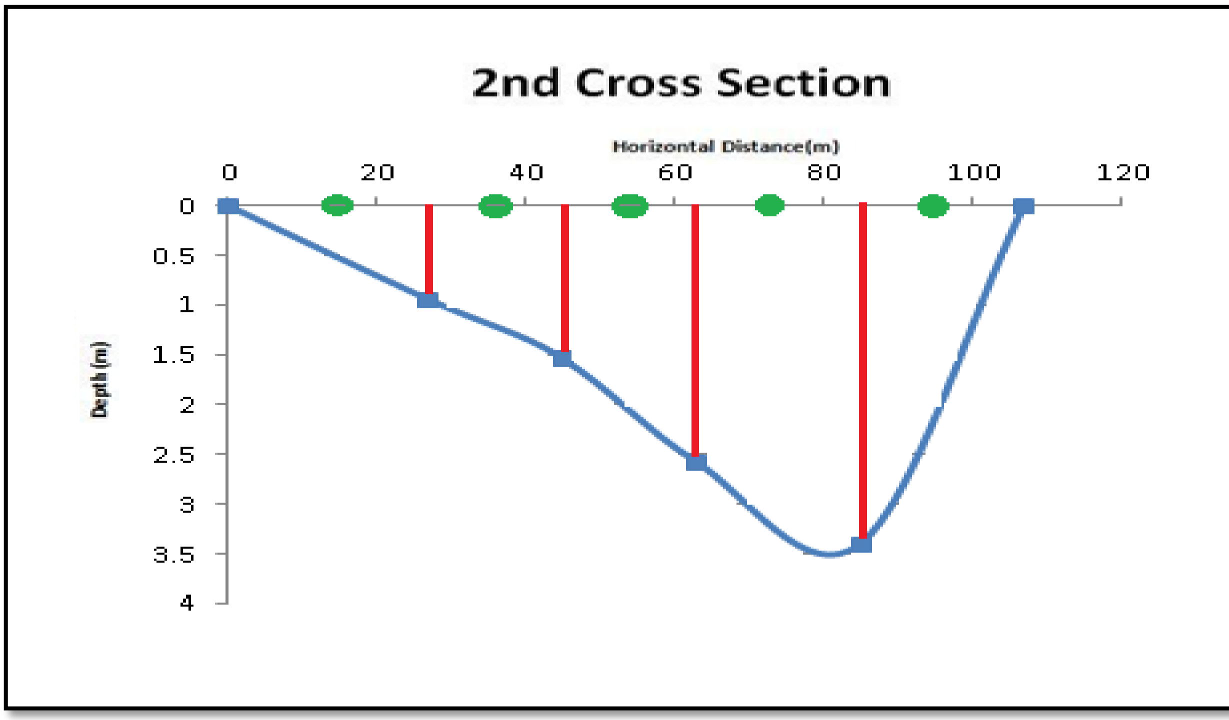
5.4. Float Method

The profiles of the cross sections are shown below.

FIRST CROSS SECTION				
Interval	Distance	Accumulated distance	Depth	Section Area
0	0	0	0	0
1	47.17	47.17	2.452	57.83042
2	23	70.17	6.752	105.846
3	18	88.17	10.172	152.316
4	22	110.17	7.182	190.894
5	18.68	128.85	0	67.07988



SECOND CROSS SECTION				
Interval	Distance	Accumulated distance	Depth	Section area
0	0	0	0	0.00
1	26.8	26.8	0.942	12.62
2	18	44.8	1.532	22.27
3	18	62.8	2.572	36.94
4	22	84.8	3.402	65.71
5	22	106.8	0	37.42



The correction coefficient used to determine the average velocity was 0.92. Then the computed discharge by float method, at 2.78 gage height, was 240.62 cubic meters per second. The summary of the computation is shown below:

Result of Discharge Observation By Float									
Measuring Line	Time of Drop	Travelling Time (sec)	Velocity of Float (m/s)	Correction Coefficient	Corrected Velocity (m/s)	Divided Area (sq. meters)			Divided Q (cu. meters per second)
						Section 1	Section 2	Ave Area	
1	11:00 AM	732.07	0.20	0.92	0.19	57.83042	12.6228	35.22661	6.64
2	11:15 AM	198.95	0.75	0.92	0.69	105.846	22.266	64.056	44.43
3	11:20 AM	215.625	0.70	0.92	0.64	152.316	36.936	94.626	60.56
4	11:25 AM	194.23	0.77	0.92	0.71	190.894	65.714	128.304	91.16
5	11:30 AM	190.63	0.79	0.92	0.72	67.07988	37.422	52.25094	37.83
Total Discharge									240.62

6. Development of a Rating Curve, Equation and Table

One of the goals of discharge measurement is to establish a rating curve defined by measured discharges at various water surface elevations. Based on actual discharge data, an equation can be formulated that would best describe the observations in such a way that if the equation would be plotted out in a graph, the curve that forms "best-fit" the distribution of the data. With a rating equation, a hydrologist can estimate discharges at various water levels, even those water elevations not present in the actual data. The discharge for every water level, based on the rating equation, is then presented in a rating table. This would then serve as a guide for the hydrologist.

In the following sections, a rating curve will be established. Values for discharge at various levels of elevation are computed through an excel suite provided by Mr Hilton Hernando, which is based on manning's equation.

6.1. Cross section survey

The cross section directly under the bridge on the downstream side will be used in estimating the discharge at various levels. For that, the elevation profile of the ground below the bridge would be needed. With the use of a sounding rope, group 1 of the HTC class did the survey for the area, measuring distances from the bridge railing to the ground below.

PAMPANGA RIVER BED PROFILING

Arayat, Pampanga

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

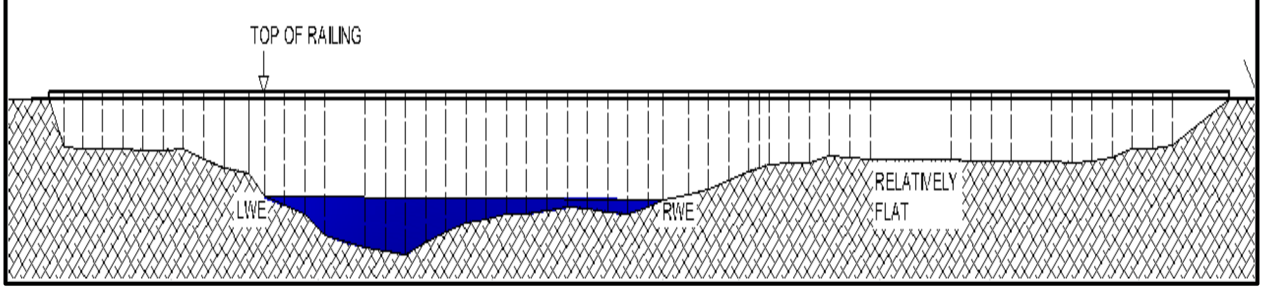
Bridge Measurements:
Heigth of Railing to Curb: 0.75 m
Height of Curb to Ground Level: 0.16 m

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

PAMPANGA RIVER CROSS SECTION
SAN AGUSTIN BRIDGE, ARAYAT PAMPANGA



The survey did by group 1 measured only the distance from bridge railing to ground; the discharge calculations require ground elevation. To convert the given depths to MSL elevations, the MSL elevation of the bridge curb measured by group 4 was taken into account. The bridge curb was at 15.562 meters AMSL, and adding the height of the railing from the curb (0.75 meters), the MSL height of the bridge railing was at 16.312 meters. The difference between this value and the corresponding depths give out the elevations of the ground below the bridge.

The resulting data are the entered on a cross section excel suite that computes for width, area, wetted perimeter and hydraulic radius for a given water surface elevation. Note that in this survey, the bridge was assumed to be straight with no piers obstructing the river.

6.1.1. <u>Discharge estimation</u>

				Date:	Oct. 23, 2013			
station	distance	elevation	water sfc.	depth	mean depth	area	wetted perimeter	remarks
0.00		15.402	15.40	0.00				
3.80	3.80	8.712	15.40	6.69	3.35	12.71	7.69	
8.34	4.54	8.512	15.40	6.89	6.79	30.83	4.54	
13.34	5.00	8.512	15.40	6.89	6.89	34.45	5.00	
18.34	5.00	8.342	15.40	7.06	6.98	34.88	5.00	
23.34	5.00	8.342	15.40	7.06	7.06	35.30	5.00	
28.34	5.00	8.422	15.40	6.98	7.02	35.10	5.00	
33.34	5.00	7.052	15.40	8.35	7.67	38.33	5.18	
38.34	5.00	5.912	15.40	9.49	8.92	44.60	5.13	
43.34	5.00	5.142	15.40	10.26	9.88	49.38	5.06	
49.54	6.20	1.762	15.40	13.64	11.95	74.09	7.06	
53.34	3.80	0.742	15.40	14.66	14.15	53.77	3.93	
58.34	5.00	-0.548	15.40	15.95	15.31	76.53	5.16	
63.34	5.00	-3.568	15.40	18.97	17.46	87.30	5.84	
68.34	5.00	-5.318	15.40	20.72	19.85	99.23	5.30	
78.34	10.00	-5.258	15.40	20.66	20.69	206.90	10.00	
83.34	5.00	-5.628	15.40	21.03	20.85	104.23	5.01	
88.34	5.00	-6.168	15.40	21.57	21.30	106.50	5.03	Thalweg
93.34	5.00	-4.388	15.40	19.79	20.68	103.40	5.31	
98.34	5.00	-3.078	15.40	18.48	19.14	95.68	5.17	
103.34	5.00	-1.688	15.40	17.09	17.79	88.93	5.19	
108.34	5.00	-1.318	15.40	16.72	16.91	84.53	5.01	
113.34	5.00	-0.678	15.40	16.08	16.40	82.00	5.04	
118.34	5.00	-0.478	15.40	15.88	15.98	79.90	5.00	
123.34	5.00	-0.078	15.40	15.48	15.68	78.40	5.02	
128.34	5.00	0.342	15.40	15.06	15.27	76.35	5.02	
133.34	5.00	0.292	15.40	15.11	15.09	75.43	5.00	
138.34	5.00	-0.198	15.40	15.60	15.36	76.78	5.02	
143.34	5.00	-0.528	15.40	15.93	15.77	78.83	5.01	
148.34	5.00	0.532	15.40	14.87	15.40	77.00	5.11	
152.14	3.80	1.482	15.40	13.92	14.40	54.70	3.92	
158.34	6.20	2.132	15.40	13.27	13.60	84.29	6.23	
163.34	5.00	2.952	15.40	12.45	12.86	64.30	5.07	
168.34	5.00	4.092	15.40	11.31	11.88	59.40	5.13	
173.34	5.00	5.362	15.40	10.04	10.68	53.38	5.16	
175.84	2.50	5.902	15.40	9.50	9.77	24.43	2.56	
178.34	2.50	6.382	15.40	9.02	9.26	23.15	2.55	
183.34	5.00	6.402	15.40	9.00	9.01	45.05	5.00	
188.34	5.00	6.402	15.40	9.00	9.00	45.00	5.00	
193.34	5.00	7.442	15.40	7.96	8.48	42.40	5.11	
198.34	5.00	7.152	15.40	8.25	8.11	40.53	5.01	
203.34	5.00	6.982	15.40	8.42	8.34	41.68	5.00	
208.34	5.00	6.982	15.40	8.42	8.42	42.10	5.00	
213.34	5.00	6.982	15.40	8.42	8.42	42.10	5.00	
218.34	5.00	6.982	15.40	8.42	8.42	42.10	5.00	
223.34	5.00	6.982	15.40	8.42	8.42	42.10	5.00	
228.34	5.00	6.722	15.40	8.68	8.55	42.75	5.01	
233.34	5.00	6.752	15.40	8.65	8.67	43.33	5.00	
238.34	5.00	6.752	15.40	8.65	8.65	43.25	5.00	
248.34	10.00	6.852	15.40	8.55	8.60	86.00	10.00	
253.34	5.00	6.602	15.40	8.80	8.68	43.38	5.01	
258.34	5.00	6.682	15.40	8.72	8.76	43.80	5.00	
263.34	5.00	7.262	15.40	8.14	8.43	42.15	5.03	
268.34	5.00	8.412	15.40	6.99	7.57	37.83	5.13	
273.34	5.00	8.542	15.40	6.86	6.93	34.63	5.00	
278.34	5.00	8.912	15.40	6.49	6.68	33.38	5.01	
292.34	14.00	15.402	15.40	0.00	3.25	45.43	15.43	
Total Width	**292.34**							
Total Area	**3363.893**							
W. P (P)	**302.21**							
Hydraulic Radius ®	**11.13098**							
Mean sect. Depth	**11.50678**							

The table on the previous page shows the summary of the elevation profile of the whole cross section, enclosed with a water surface elevation equivalent to the elevation of the bridge railing in order to compute for the width, total area, wetted perimeter, and hydraulic radius when the water reaches the bridge railing. Computations for the mentioned parameters are repeated at other water surface elevations using the cross section sheet. There will be various values of these parameters for a whole range of water elevation, which are then entered in another excel suite that estimates discharge. The group's calculations are summarized below.

Pampanga River @ Arayat								
(based on cross-section undertaken on October 2013)								
Elevation of "0" of S.G.=		0.000	m.(AMSL)					
n=	0.030	I=	0.000145					
Elevation	Equivalent	Area	Width	W.P.	hyd radius	Discharge	Remarks
MSL (m)	G.H.(m)	a (m^2)	w (m)	s	r	Q (cumecs)	
15.40	15.402	3363.89	292.34	302.21	11.13	6731.22	bank full/ level with bridge road
15.00	15.000	3247.38	291.50	300.97	10.79	6364.56	
14.00	14.000	2956.91	288.60	297.38	9.94	5488.03	
13.00	13.000	2670.61	286.30	294.09	9.08	4665.80	
12.00	12.000	2385.26	283.15	290.25	8.22	3898.89	
11.00	11.000	2104.14	281.00	287.13	7.33	3186.39	
10.00	10.000	1824.65	278.00	283.48	6.44	2534.26	
9.00	9.000	1548.21	275.30	279.97	5.53	1943.30	
8.00	8.000	1291.18	236.10	240.54	5.37	1588.87	
7.00	7.000	1053.37	162.40	166.46	6.33	1446.52	
6.00	6.000	902.84	137.90	141.81	6.37	1244.84	
5.00	5.000	769.53	128.20	131.89	5.83	1001.07	
4.00	4.000	643.90	122.10	125.45	5.13	769.04	
3.00	3.000	525.10	116.30	119.21	4.40	566.34	
2.00	2.000	412.62	108.00	110.58	3.73	398.45	
1.00	1.000	310.25	98.00	100.34	3.09	264.30	
0.50	0.500	262.09	93.50	95.73	2.74	205.88	
-1.00	-1.000	163.04	56.40	57.80	2.82	130.64	
-2.00	-2.000	110.61	40.90	42.35	2.61	84.20	
-3.00	-3.000	72.23	36.90	37.84	1.91	44.61	
-4.00	-4.000	39.10	30.70	31.30	1.25	18.20	
-5.00	-5.000	11.85	25.00	25.27	0.47	2.87	1.168m from thalweg (thalweg @ 6.168 below MSL)

6.1.2. 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	$\Sigma X^2 =$	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	$\Sigma (X^2)$ =	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 = $10^{a\wedge}$ =	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:

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

6.1.3. 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:

7. Summary and Conclusions

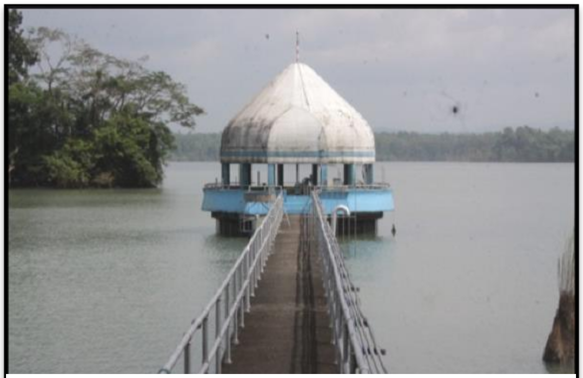
The four different methods of discharge measurement (indirect and direct) have their limitations and strengths depending on the practical use of each during flood and non-flood seasons. Each scenario has the best method to be used but it depends on the availability, accessibility, performance based on that equipment/instrument itself. For slope area method, a tedious and iterative method provides good information on the discharge of the streams given accurate instruments. The limitation if this method was identifying the floodmarks.

For the float method, it is the easy way to measure peak and it is essential during flooding time. The only limitation of this method was float traverse to other side of the river during low flow. The ADCP has proven to be beneficial to stream gauging in several ways. The only limitation was during high flow, it is difficult to traverse the river.

8. Field Visits

La Mesa Dam (October 15, 2013 Tuesday)

As part of the activity, we visited some dams and first stop was the La Mesa Dam and it is Greater Lagro, Quezon City, Philippines. It is part of the Angat-Ipo-La Mesa water system, which supplies most of the water supply of Metro Manila. One of the personnel there Mr. Maxim gives some information about the facilities and the operation of the dam. As the lecture goes on, he explained that La Mesa Dam has no direct connection in flooding downstream especially in Marikina City because it has no spill gate which controls the flood, it is just an overflow. The main usage of this dam is for water supply in Metro Manila.



A photo of the release water station

A photo of the La Mesa Headworks Office

<u>Pantabangan Dam</u> (October 19, 2013 Saturday)

Pantabangan Dam was the second dam we had visited. It was a 4-hour trip going there. The long and tiring trip was paid off by the beautiful scenery that surrounds the area. Upon arriving, the staffs gave us some food to eat because it is already 12 noon and while eating, they started to present the lecture. The main priority of this dam is for irrigation. Pantabangan Dam has its own flood forecasting station that always monitors the water level. It has 3 spillway gates so whenever the water reaches the critical level, the dam need to released water to avoid any major damages to the dam and to its downstream areas.

Behind the dam's spillway

Spillway gates

<u>Cong Dadong Dam</u> (October 21, 2013 Monday)

After all the methods was done, we visited the Cong Dadong Dam which is located upstream of the Pampanga River. It was named after former President Diosdado Macapagal. The term Dadong means “kuya” and Cong is short for Congressman. A fish ladder was also installed just after the gates as another source of living. The main purpose of the dam was to supply water for Irrigation.

Entrance of the dam

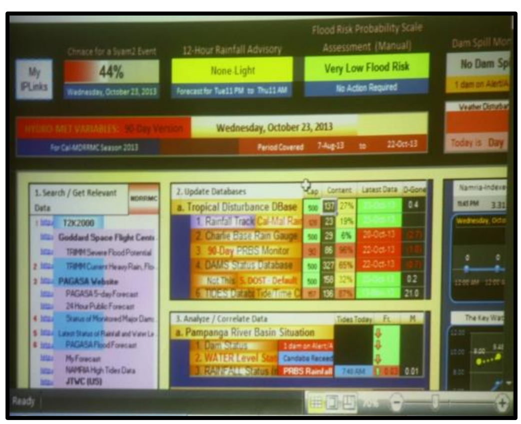

Fish Ladder


Spillway gates

<u>Municipal Disaster Risk Reduction and Management Council</u> at Calumpit Bulacan (October 23, 2013)

MDRRMC was formed due to the continuous flood problem in Bulacan especially in Calumpit, so the Local Government Unit make a solution how to get some information’s about the flooding events in the area. They come up to make a designed/a system in an excel form. The designed was very helpful to the said area because it records adequate information and gives awareness to people. They had also a flood color indicator which corresponds to water level.

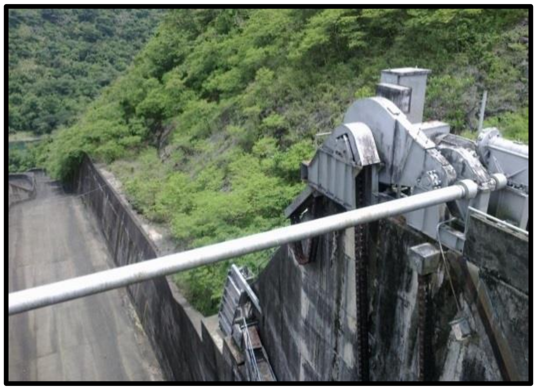

Water Level Indicator



Excel form of the system

Angat Dam (October 24, 2013)

The last day of our activity was visiting a Dam which is the Angat Dam. Angat Dam is a concrete water reservoir embankment hydroelectric dam that supplies the Manila metropolitan area water. It was a part of the Angat-Ipo-La Mesa water system.concrete water reservoir embankment hydroelectric dam that supplies the Manila metropolitan area water.



Spillway

Spillway Upstream Side