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Assessing the Resurgent Irrigation Development Program of the Philippines – Water Resources Component

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Assessing the Resurgent Irrigation Development Program of the Philippines – Water Resources Component

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Abstract

This study is to assess the irrigation service areas of AMRIS and PDRIS benchmarked against design area water availability, land use (including flood vulnerability), and status of irrigation facilities, using resource assessment and watershed and irrigation modeling. Highlight of the findings are: irrigation area of NIA-AMRIS fell below design area due to urbanization, lowered height of Bustos Dam, complicated by competing use of water for hydropower. The PDRIS system has likewise only realized half of the target irrigation service area due to urbanization and flooding, as well as low diversion dam height of Cong Dadong Dam.

The AMRIS irrigation canal network was thoroughly investigated through hydraulic modeling and simulation. There are areas within the system that may not at all be irrigated since most canals had reduced capacities due to sedimentation, rendering gravity flow inefficient. Thus, there is a need to develop effective canal maintenance scheme of the AMRIS and also to reassess the operation schemes for efficient canal operations.

The following are major recommendations in this study. First is reassessment of the details of the operations should be done since the feasibility studies of these irrigation systems seem lacking in detailed technical assessment of performance of the irrigation systems with regard to reliability of water sources (in time and space). Second, periodic operational studies once the system is already built is practically never done but simply to make adjustments based on actual observations and experiences thus the need for periodic review and updating of operations schemes and strategies and preferably this is done every 3 years or as needed. It is important that periodic appraisal or assessment of the efficiency of irrigation water delivery operations as illustrated here through hydraulic model simulations should be conducted for proper maintenance and upgrade of irrigation facility as needed.

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Assessing the Resurgent Irrigation Development in the Philippines: Water resources component

Guillermo Q. Tabios III and Tomas de Leon[*]

1. Introduction

In the Pampanga River Basin (excluding O'Donnell, Camiling and west of Agno River Basins), there are five (5) major national irrigation systems (NIS) namely Upper Pampanga River Irrigation System (UPRIS), Casecnan, Balog-Balog, Pampanga Delta (PADRIS) and Angat-Maasim River (AMRIS). Two (2) of these NIS, namely – AMRIS and PADRIS were constructed with design service areas of 31,400 ha and 11,540 ha, respectively. However, since the AMRIS irrigation canal (conveyance) system was completed in mid-1970's, its actual irrigated area has only reached as much as 27,000 during the dry season and only as much as 18,000 ha during the wet season since farmers do not risk planting in flood-prone areas. In the case of PADRIS, after project completion in 2002, it has only been able to irrigate as much as 6,900 ha during the dry and lesser by 1,000 ha during the wet season due to risk of flooding. In the above-mentioned irrigation systems, while physical features like slope, geology, soils and topography may have led to overestimation of design service areas, other major factors such as water availability, land use change, under developed irrigation facilities and frequent flood inundation of the area resulted in actual, historical irrigated areas annually to be below their design irrigation areas.

This study is to assess the design irrigation service areas as originally planned compared to the actual service areas in relation to water availability, land use (including flood vulnerability) and status of irrigation facilities. The approach here is to evaluate the ability (how much) of the water resources (water source), land resources (slope, soils and land use) as well irrigation facilities to irrigate so much area (hectares) through watershed and irrigation modeling and simulation. The two (2) national irrigation systems assessed in this study are: Angat-Maasim River Irrigation System, (AMRIS) and Pampanga Delta River Irrigation System (PADRIS).

2. Angat-Maasim River and Pampanga Delta Irrigation Systems

Described below is the status and conditions of the Angat-Maasim River Irrigation Systems (AMRIS) and Pampanga Delta River Irrigation System (PADRIS). Certain materials presented below were taken from the study of Tabios and David (2014) and also Tabios (2017).

2.1. Angat-Maasim River Irrigation System (AMRIS)

Figure 1 shows the AMRIS service area where the irrigation water supply is mainly coming from the Angat Reservoir releases Bustos Dam. It may be noted that the Angat Reservoir inflows comes from the Angat watershed as well as from Umiray watershed through the Umiray transbasin tunnel. Angat Reservoir also releases through Ipo Dam for Metro Manila's MWSS domestic water supply thus it is viewed as a competing water use to irrigation water

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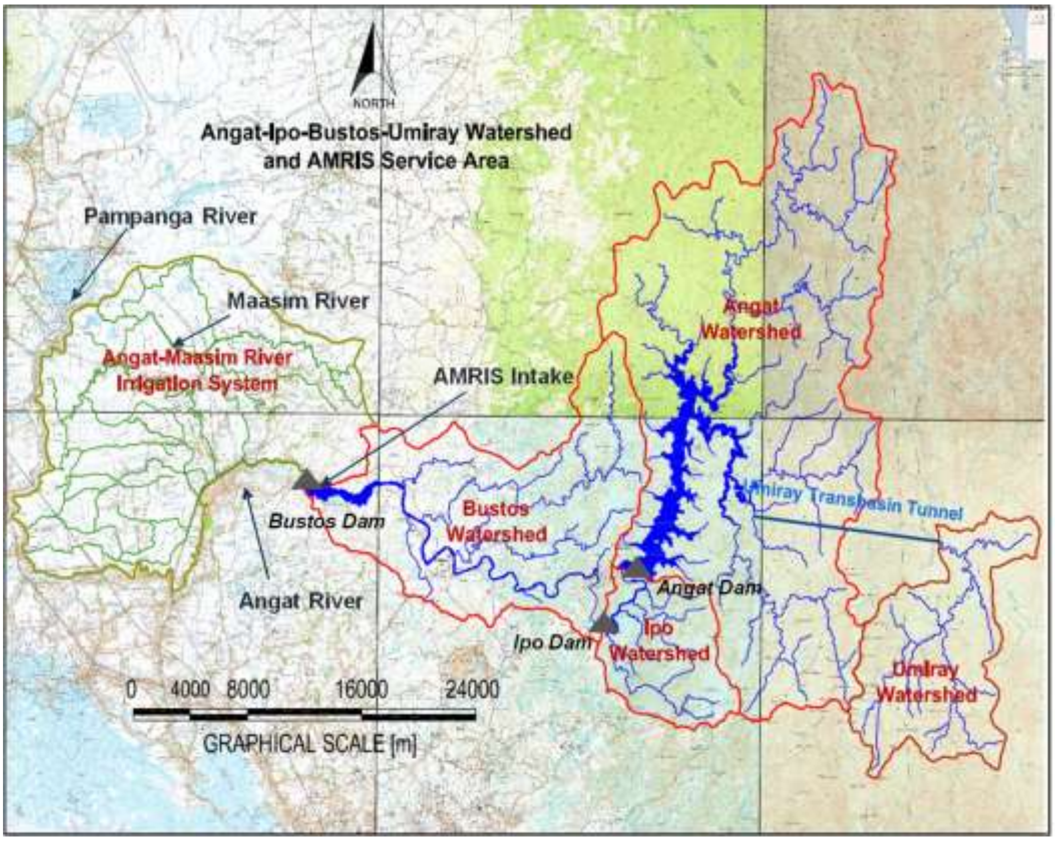
releases to AMRIS as discussed by Tabios (2016). The local inflows from Bustos watershed (between Angat Reservoir and Bustos Dam) also contribute to Bustos Dam inflows and thus become part of the AMRIS irrigation water supply. Likewise, local inflows of Ipo watershed flow into Ipo Dam thus becomes part of the domestic water supply to Metro Manila.

It may be useful to note that the watershed areas associated to each watershed in Fig. 1 are as follows: (1) Angat watershed is 546.2 sq. kms; (2) Umiray watershed is 124.4 sq. kms; (3) Ipo watershed is 72.3 sq. kms; and, (4) Bustos watershed is 233.3 sq. kms.

The watershed area covered by AMRIS as shown in Fig. 1 is 314.8 sq. kms.

Figure 1. Angat Reservoir water resource system including the Angat-Maasim River Irrigation System (AMRIS). [From Tabios and David, 2014]



Data of historical irrigated service areas from NIA Office in Quezon City showed that during the wet season (June-October) and dry season (November-April) from 1976 to 2008, the irrigated area has been declining to an average of about 17,500 ha (hectares) during the wet season in the last 10 years from the original 22,000 ha in the 1970's while the dry season irrigated area averaged around current areas of 24,000 ha from the original 27,500 ha in the 1970's. Most important to note is that the original design service area of about 31,400 ha was never attained.

With these historical irrigated areas, a simple water balance computation for AMRIS planted with paddy rice was shown by Tabios and David (2014) that with the average daily paddy rice water requirements for the case without wasted water is 1.12 lps/ha (liters/sec/ha) or 0.00112 CMS/ha and 1.67 lps/ha or 0.00167 CMS/ha for the case with wasted water. During the 4-month cropping season, the range of irrigation water requirement ranges from 19.6 to 29.2 CMS (for without and with wasted water) during the wet season for the 17,500 ha area planted and from 26.88 to 40.1 CMS during the dry season for the 24,000 ha.

Table 1 shows the historical releases (in CMS) of Angat Reservoir to AMRIS as well as MWSS. Also shown in Table 1, are the monthly water allocations used by NWRB for allocating or scheduling monthly releases to AMRIS while the for MWSS, it is fixed to 46 CMS. It is seen here that the average annual historical releases (on daily basis) is 27.46 CMS which is around the midpoint of the range of paddy rice water requirement of 19.6 CMS (minimum of case without wasted water) and 40.1 CMS (maximum of case with wasted water).

Table 1. Monthly averages of historical releases to MWSS and AMRIS from Angat Reservoir calculated from daily data (1996-2013) including NWRB allocation for NIA-AMRIS. [from Tabios, 2017]

Month	Historical Releases to MWSS (CMS)	Historical Releases to NIA-AMRIS (CMS)	NWRB Allocation for NIA-AMRIS (CMS)
Jan	37.97	38.50	36.00
Feb	39.30	35.80	39.86
Mar	38.74	27.94	31.00
Apr	40.01	14.12	15.50
May	41.09	7.94	0.00
Jun	43.88	15.58	27.90
Jul	33.17	20.97	28.00
Aug	29.01	21.51	25.00
Sep	29.99	24.87	22.73
Oct	34.21	28.56	13.00
Nov	32.82	39.80	17.57
Dec	35.19	53.88	34.00
Annual Average	36.28	27.46	24.21

Table 2 shows the flow duration analysis of historical and computed daily flows using the Sacramento-based watershed model of Angat Reservoir inflows, Ipo Dam local inflows, Bustos Dam local inflows and Umiray River flows to Angat. As seen in this table, the range of dependable Bustos Dam local inflow at 80% (about 290 days a year) and 60% (about 220 days a year) is 2.97 and 8.66 CMS, respectively which cover the deficit of about 6 CMS mentioned above. Also, the Angat Reservoir releases as allocated by NWRB on a monthly basis with an average daily flow of 24.21 CMS is adequate enough for AMRIS despite the NWRB allocation for MWSS is 46 CMS. But it should be noted that the actual historical releases from Angat Reservoir to AMRIS is 27.46 CMS while the actual releases to MWSS is only about 36.28

CMS although this may be augmented by Ipo Dam local inflows which has a daily average of 8.72 CMS.

Table 2. Flow duration analysis of historical and watershed model computed daily flows of Angat Reservoir inflows, Ipo Dam local inflows, Bustos Dam local inflows and Umiray River flows to Angat. [From Tabios, 2017]

	Angat Reservoir Inflows (CMS)			Ipo Dam Local Inflows (CMS)	Bustos Dam Local Inflows (CMS)	Umiray River Flow to Angat Reservoir (CMS)
	Historical Data (1996-2012)	Model Computed (1996-2012)	Model Computed (1974-2013)			
Average	63.01	63.30	65.98	8.72	28.18	15.02
Minimum	0.00	1.68	0.71	0.09	0.31	0.16
Maximum	1526	2309	2988	398	1278	684
Q90%	4.64	4.78	3.56	0.47	1.52	0.80
Q80%	12.68	8.79	6.97	0.91	2.97	1.58
Q60%	27.99	23.25	20.33	2.66	8.66	4.59
Q40%	46.50	47.11	45.80	6.02	19.53	10.40
Q20%	80.11	89.94	91.91	12.23	39.66	21.08

The big question here is why the historical, actual irrigated area of AMRIS has been less than the design irrigated area of 31,400 ha which is about 24,000 ha (or about 75% of the design area) during the dry season and about 17,500 ha (or about 55% of the design area) during the wet season. In the report of Tabios and David (2014), it was shown that during the dry season, out of 31,400 ha design service area, the effective area is about 23,000 ha since 3,000 ha is above the 20 m elevation which cannot be served by Bustos Dam (with an operational crest elevation of 18.5 m) and that 5,000 ha is already urbanized. During the wet season, an additional 5,500 ha (mostly below 7 m elevation) is flood prone area so do not risk planting this area thus leaving a total of 17,500 ha that is normally planted.

2.2 Pampanga Delta River Irrigation System (PADRIS)

The Pampanga Delta river irrigation system was completed around 2002. It has a design service area of 11,540 ha. Referring to Fig. 2, the system is divided in four distinct areas as follows: 1) West Area (upper west part) which is about 2,980 ha, 2) San Mateo Area (lower west part) which is 1,380 ha, 3) Upper East Area which is 2,943 ha, and 4) Lower East Area which is 4,677 ha.

The water source of the Pampanga Delta Irrigation System is the Pampanga River which is diverted through the Cong Dadong Dam diversion structure (see Fig. 2 for its approximate location). The physical features of Cong Dadong Dam are as follows: (1) the dam elevation is 8.6 m with a height of 1.3 m; (2) the length is fix at 850 m plus a movable length of 150 m; (3)

a sediment flushing sluice gate with width of 36.5 m; and, (4) the irrigation water intake water level is at 8.5 m with a maximum discharge of 20.18 CMS.

For the design service area of 11,540 ha, the irrigation water supply from the Pampanga River is fairly adequate. It has been computed in this study that the 80% dependable flow (Pampanga River flow over 300 days a year) as shown in Fig. 4 is 108 CMS thus the only constrain is the intake structure of the diversion dam which has a maximum intake discharge of 20.18 CMS. In likewise manner as AMRIS, for a high end of 0.00167 CMS (1.67 liters/sec) per ha water requirement for paddy rice, the average daily water requirement is about 19.3 CMS for the design area of 11,540 ha.

Figure 2. Pampanga Delta Irrigation System including its physical features. [From Tabios and David, 2014]

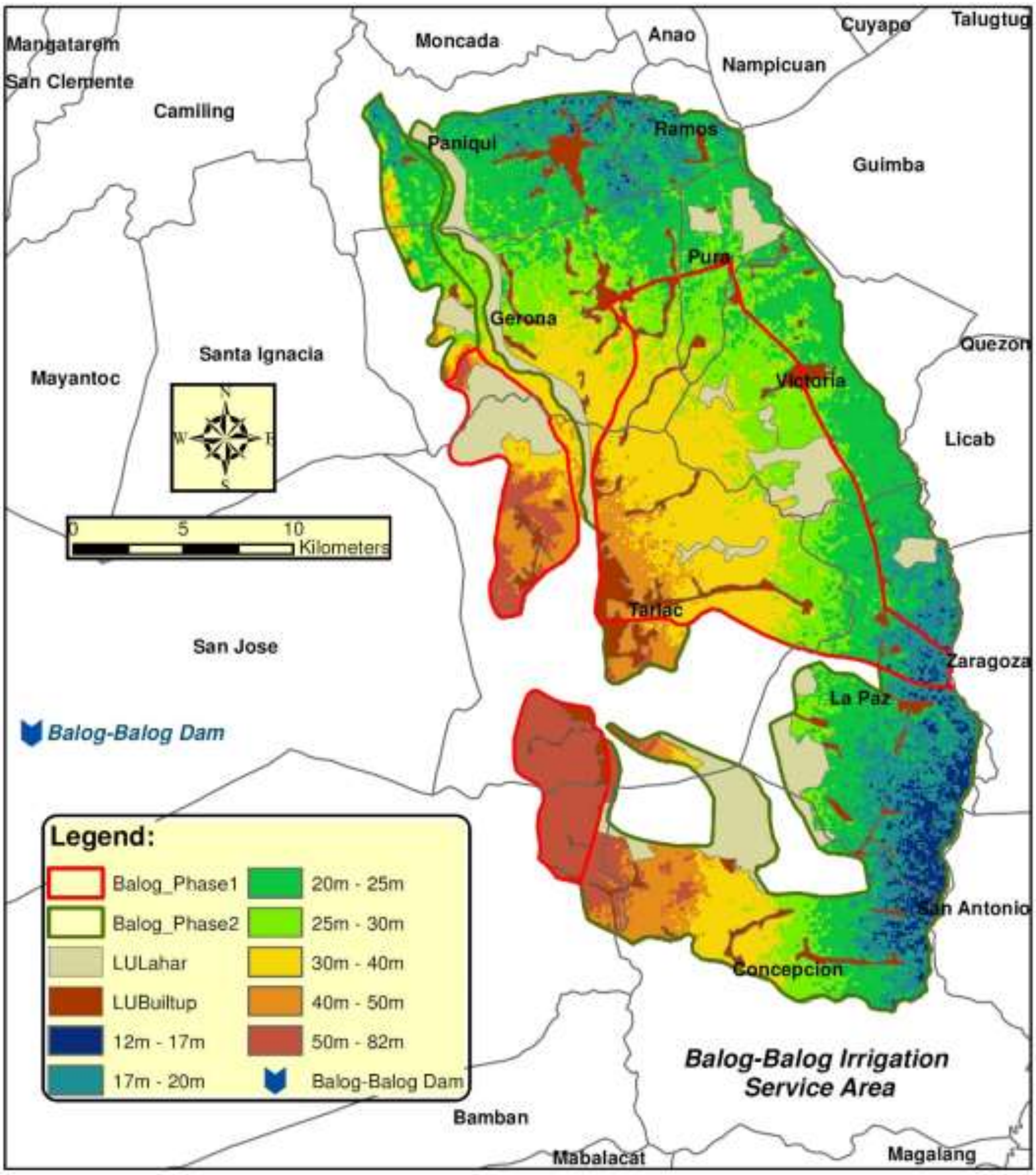


Figure 3. Pampanga River Basin to be covered by watershed modeling to generate inflows at the Cong Dadong Diversion Dam to PADRIS.

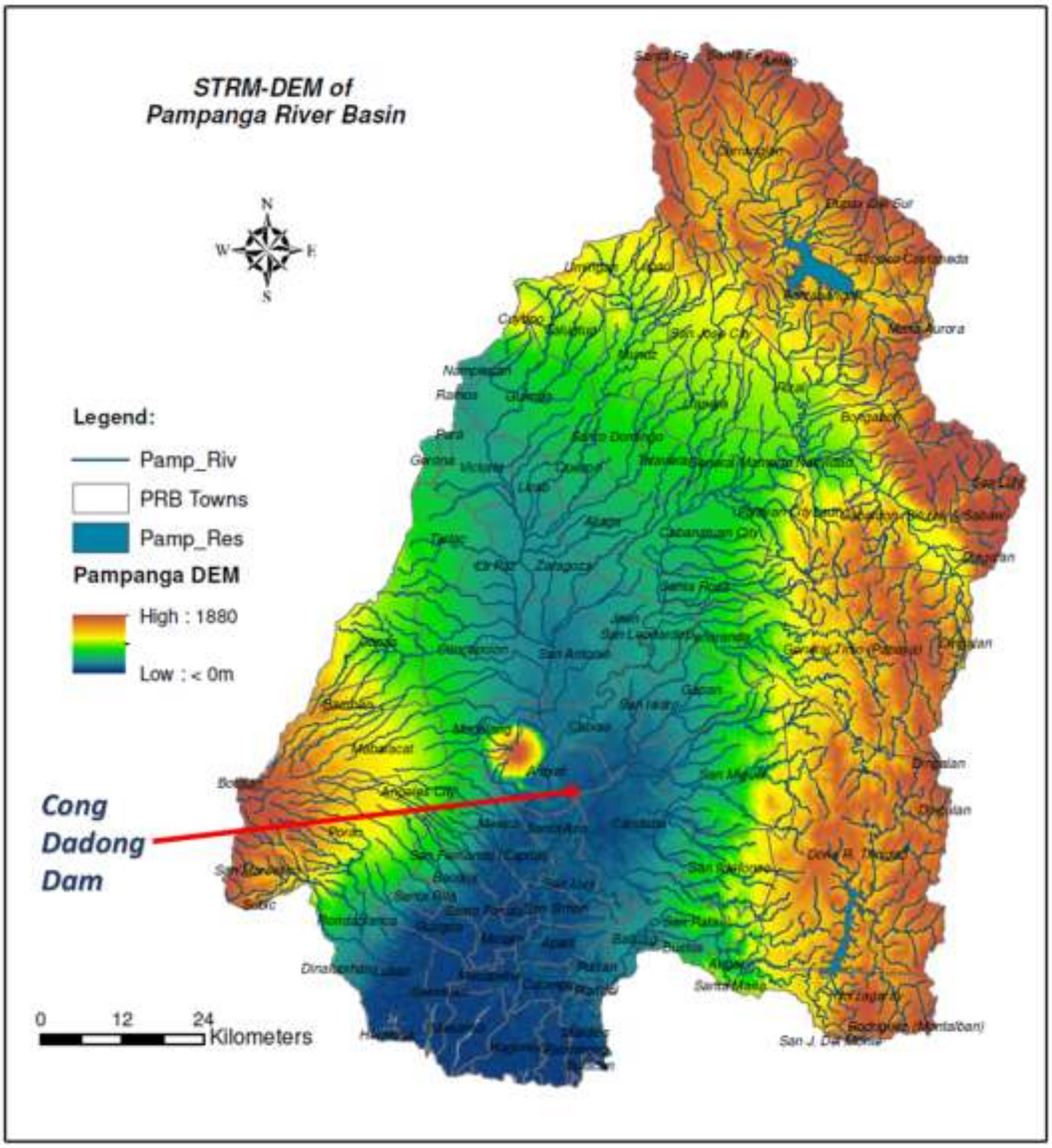
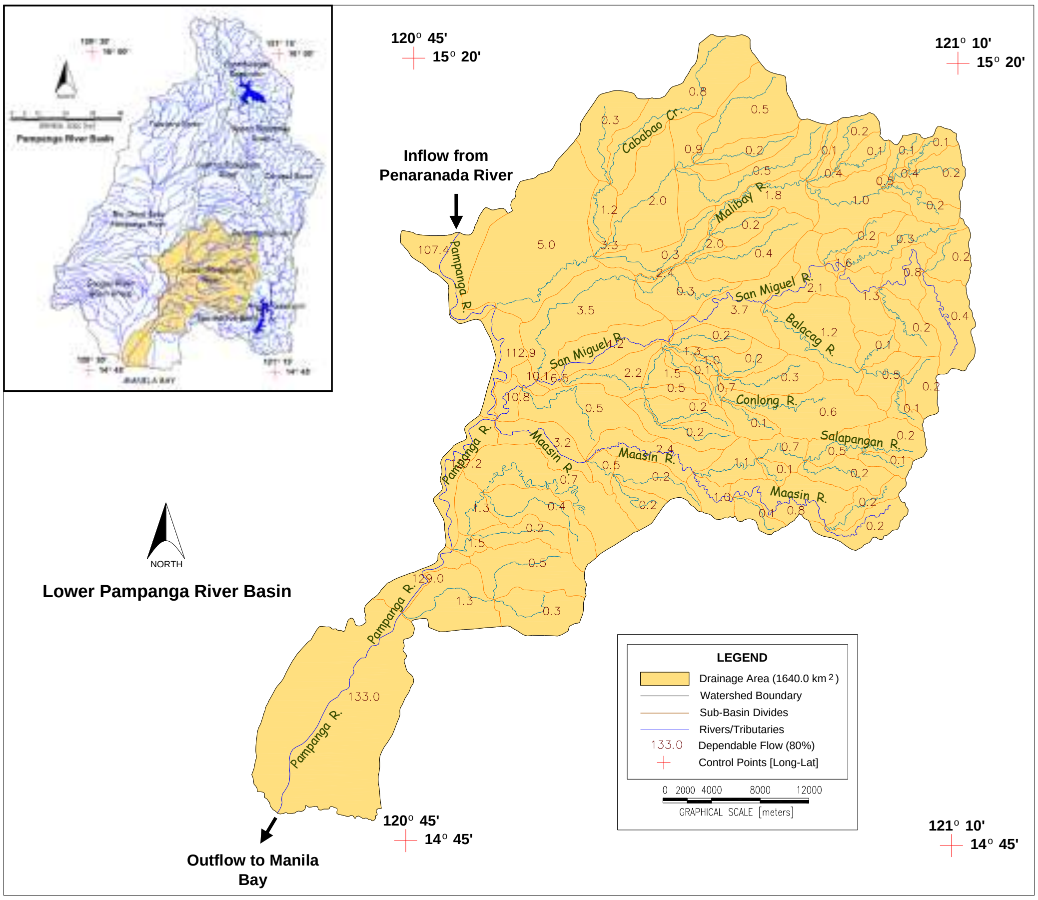


Figure 4. Long-term 80% dependable daily flows (m^3/s) over the Lower Pampanga River.



Data from NIA (Inocencio, A. – see bibliography section), the historical irrigated service areas of Pampanga Delta irrigated system from 2003 to 2014 during the wet season, is about 5,000 ha which is about 35% of the design service area of 11,540 ha while during the dry season, it is a maximum 6,900 ha which is about 60% of the design area.

Based on GIS map of this area, estimates of areas covered according to physical features or land use are as follows: (1) the built-up or urbanized area is about 1,050 ha; (2) areas with fish ponds is about 1,650 ha; (3) areas with elevation of 8.5 m or higher thus above intake level at Cong Dadong Dam is about 2,000 ha; and, (4) flood prone areas during the wet season which are normally below 3 m elevation is about 950 ha.

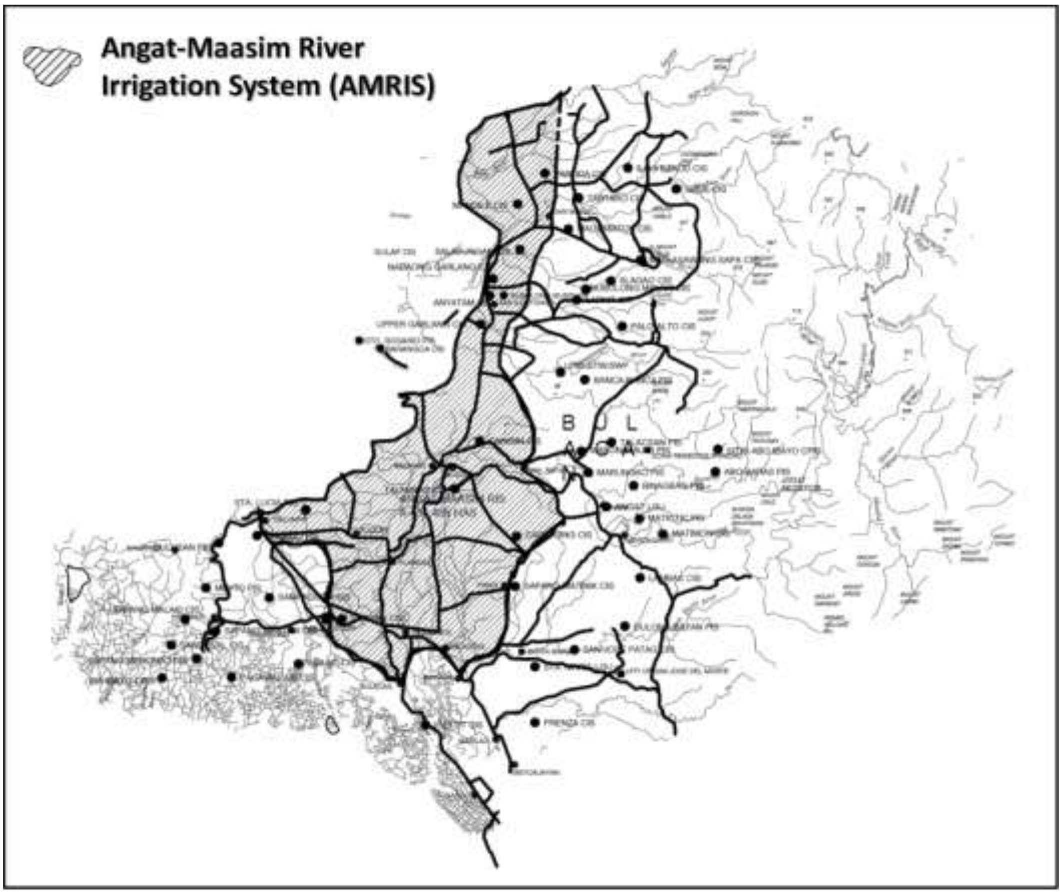
With the above information, the sum of the first three (3) land areas is 4,700 ha so that the remaining area out of 11,5400 ha that can be irrigated is 6,840 ha. During the wet season, the additional 950 ha that are flood prone reduces the irrigated area to 5,890 ha. In discussion with NIA personnel during our field visit (see next section), additional explanations were given are such that: 1) there are locally elevated paddy areas that cannot be reached by water (by gravity) which require land grading or cutting; and, 2) downstream water users may not be get water due to over allocation or extraction upstream.

3. Hydraulic Modeling of Irrigation Canal Network

3.1 Hydraulic Model Used and the AMRIS and PADRIS Canal Network

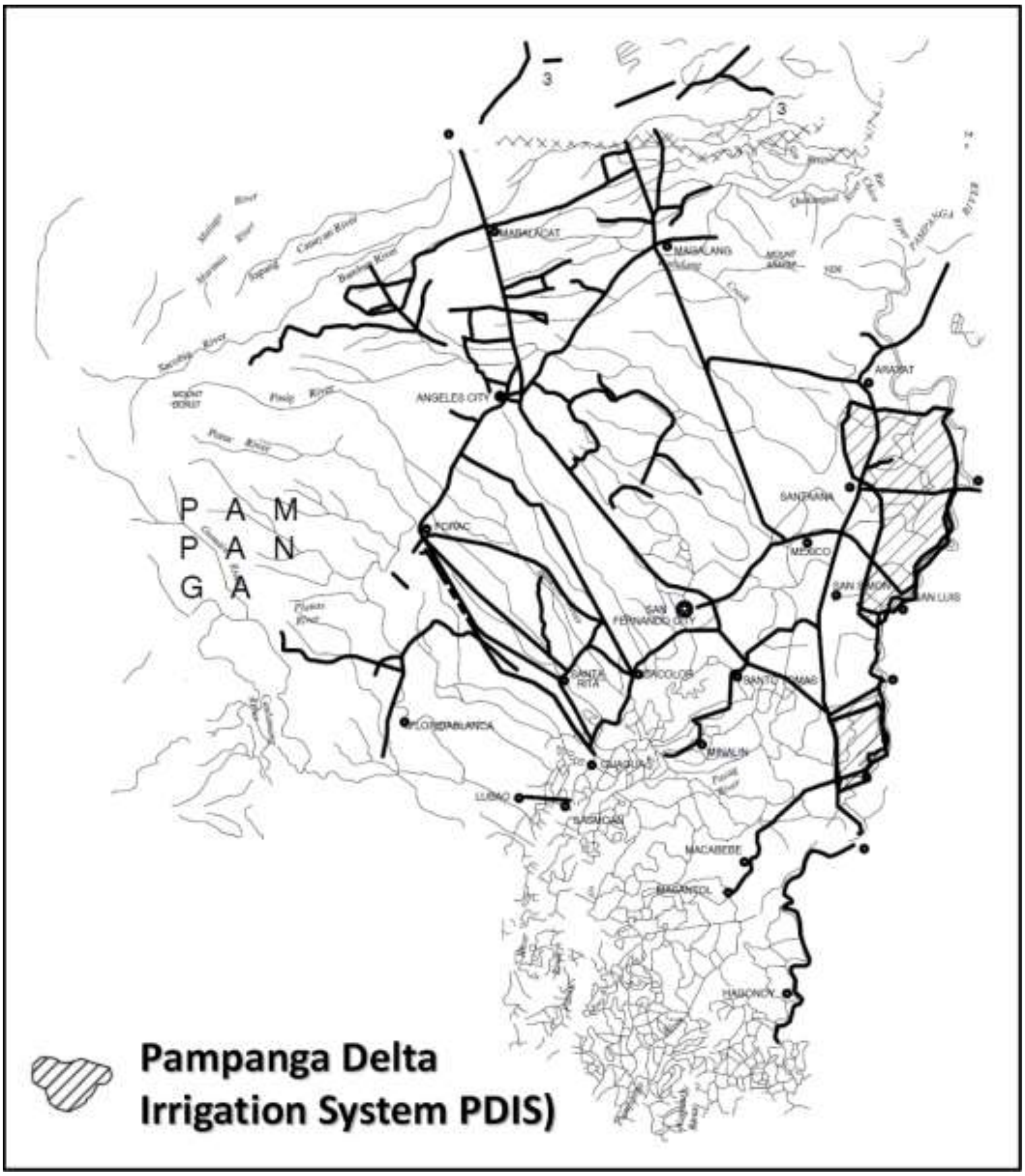
For this study, the unsteady flow model component of the HEC-RAS of the U.S. Army Corps of Engineers (1995) was utilized to simulate the canal hydraulics of AMRIS with specified inflows into the irrigation canal network. Essentially, hydraulic model is used to evaluate the ability of AMRIS to properly deliver the irrigation water in the service area. Details of the hydraulic model input and implementation is given in the next section. Fig. 5 shows the details of the AMRIS irrigation canal layout.

Figure 5. Details of the Angat-Maasim River Irrigation System canal system. [Exhibit provided by NIA, San Rafael Bulacan Office, September 2018]



To evaluate the ability and reliability of PDIS to provide irrigation water in its irrigation area, the unsteady flow model component of the HEC-RAS of the U.S. Army Corps of Engineers (1995) and the Sacramento watershed model to calculate the inflows of Pampanga River Basin and diverted at Cong Dadong Dam will be utilized. Fig. 6 shows the details of the PADRIS irrigation system and the coverage of the Pampanga River Basin watershed model in which the inflow to PADRIS are extracted from Pampanga River at Cong Dadong Dam diversion structure as indicated in the figure.

Figure 6. Details of the Pampanga Delta Irrigation System (PADRIS) canal layout. [Exhibit provided by NIA, San Rafael Bulacan Office, September 2018]



3.2 Procedure for Hydraulic Modeling of Irrigation Canal Network

The steps in the hydraulic modeling of the irrigation canal network is summarized in the flow chart given in Fig.7. It starts with the preparation of model geometry data from maps provided by NIA of the canal network. For AMRIS, Fig. 8 shows the plan view of the main canal and associate irrigation service sub-areas together with the profile of the canal. These data are needed to create the model geometry of HEC-RAS model. In Fig. 8, the picture on the right shows the actual elevations that was recorded by NIA for their plans, when they surveyed the area in the 1990s. All data was based from their plans, which contains both "actual bottom elevations" and "proposed bottom elevations". The actual bottom elevations were erroneous, as what HEC-RAS showed, while the "proposed bottom elevations" were uniform. We used the actual bottom elevations that was recorded by NIA at that time, but we weren't able to confirm these elevations on the field. We assumed that NIA did not perform further maintenance and improvement on the irrigation canals, which would result to the uniform elevations, supposedly.

The major boundary conditions in the model are the irrigation water supply from Bustos Dam (upstream inflow), and the water demands calculated based on the irrigation rates according to the wet and dry cropping seasons which are imposed at pertinent locations along main canal. In the hydraulic model simulations, what needs to be checked is if the flow demand at each of the irrigation delivery points according to the crop water requirements can be satisfied or not. Also, if there are areas that can become flooded or not depending on flow conditions.

Since there was difficulty obtaining data for PADRIS (or in fact there is not available channel network geometry data), it was decided that only the AMRIS and in particular, its North Main Canal (NMC) is subjected to hydraulic modeling and simulation. The irrigation service area associated to the NMC portion of AMRIS is about 12,200 ha which is about half irrigated area normally covered during the dry season.

Figure 7. Flow chart of steps in hydraulic modeling of irrigation canal network.

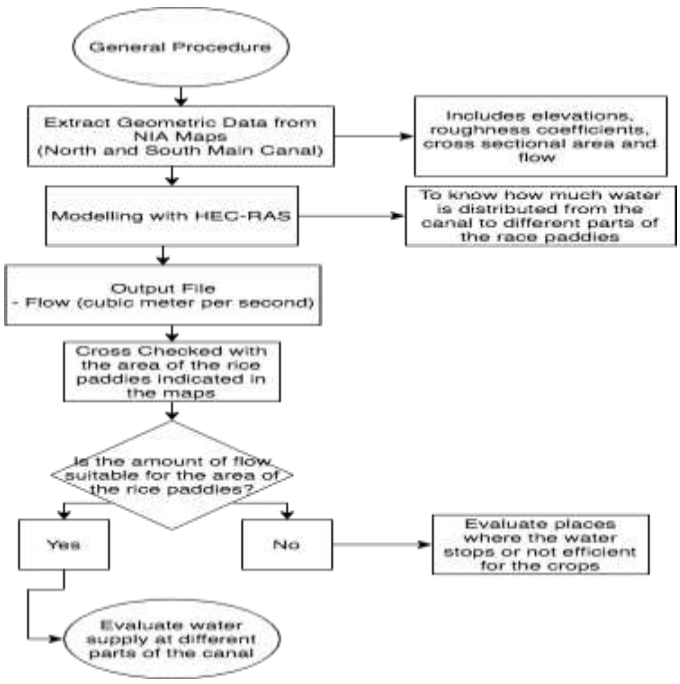
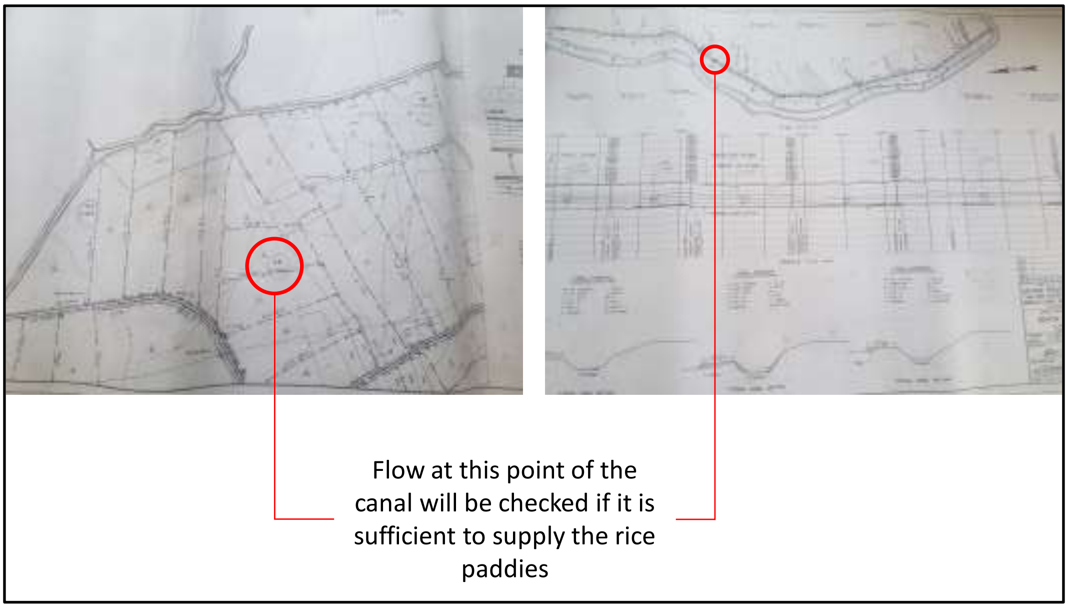


Figure 8. Plan view of irrigation canal network and profile data of main canal provided by NIA. Also shown are the irrigation service sub-areas at pertinent lateral outlets of the main canal.



4. Discussion of Results of Hydraulic Simulation of AMRIS Canal Network

The hydraulic simulation was only conducted for the irrigation service area of AMRIS associated to the North Main Canal (NMC) which covers an area of 12,200 ha. Figure 9 shows the modelled area. The assumptions are as follows: (1) flow only comes from the upstream section at the north outlet of Bustos Dam which is equal to 14.6, 18.0 and 26.65 CMS (m^3/s); (2) the upstream boundary condition is subcritical flow and downstream boundary condition is critical flow; and, (3) the actual bottom and top river elevations were considered so that the planned elevations varied with the actual elevations due to erosion and parts of the river needed to be scoured. With regard to the three (3) sets of inflows, the 18.0 CMS inflow is based on typical design irrigation water requirement of 1.5 lps/ha (0.0015 CMS/ha), while 14.6 and 26.65 CMS, represent the water requirements at the low end of 1.2 lps/ha (0.0012 CMS/ha) and at the high end of 2.2 lps/ha (0.0022 CMS/ha), respectively. A sample graphical display of HEC-RAS computer model results in a particular lateral canal of AMRIS is shown in Fig. 10 below.

Tables 3, 4 and 5 show the simulation results for inflows to NMC at 14.6, 18.0 and 26.65 CMS, respectively. Figures 11 and 12, 13 and 14 as well as 15 and 16 are the resulting water elevations and water depths at take-off to the laterals along the NMC (main canal), respectively for the three (3) sets of inflows. In the three tables, the major results shown are the differences of bank elevation and water surface at NMC which are highlighted in green if positive while red if negative. Negative differences indicate that the water at these take-off points (from main canal to lateral canal) is overflowing and perhaps simply passed through wasted downstream of the irrigation service area. Also shown are the water depths at NMC (main canal) which are highlighted in green if above 2.5 m, yellow if between 1.0 m to 2.5 m and red if below 1.0 m. The lower the water depth relative to the lateral depth, the higher lift is required to move from main canal to lateral canal.

From these results, one may ask how much water is required to sufficiently and uniformly irrigate the target service area which is 12,200 ha in this case. NIA typically sets their design irrigation requirements between 1.2 to 1.8 lps/ha (or 0.0012 to 0.0018 CMS/ha) and averages at 1.5 lps/ha. As shown in the results here, for inflow cases (delivered to the NMC) of 1.2 and 1.5 lps/ha, Tables 3 and 4, respectively show that the water depths (last column) in the main canal relative to the laterals are relatively low that it will require some pumping to transfer water from main canal to lateral canal. On the other hand, the inflow of 26.65 CMS is what is required to sufficiently and uniformly supply the target irrigation service area but this water requirement is at 2.2 lps/ha which is quite wasteful and excessive. In other words, to be able to deliver irrigation water to the entire 12,200 ha, it requires 2.2 lps/ha (26.84 m^3/s for the entire area) when only 1.8 lps/ha (21.96 m^3/s for the entire area) is needed so the difference of 0.4 lps/ha (from 2.2 minus 1.8) is excess or wasted water that go somewhere else to be able to deliver 1.8 lps the is needed for every hectare in the area.

There are various reasons why the 12,200 ha of AMRIS modeled here cannot be sufficiently and uniformly irrigated unless excessive water applied approaching 2.2 lps/ha. There are several factors and the major one is that certain channel sections have reduced capacities (i.e., shallowing canal) due to sedimentation and consequently, channel gradients or slopes of the channel network are reduced resulting in the inability to effectively deliver water over the entire area. Thus, the inability to efficiently move water from the main canal to the lateral canal even at certain take-off points in the channel network lead to difficulty in proper allocation and uniformity of water delivery to the target irrigation service areas. Definitely, it is important that periodic appraisal or assessment (every 3 years or as deemed necessary) of the efficiency of irrigation water delivery operations as illustrated here through hydraulic model simulations should be conducted for proper maintenance and upgrade of irrigation facility if needed.

Figure 9. North Main Canal (NMC) and lateral canals. Inflow point is at Bustos Dam along Angat River (located on middle, left portion of the figure).

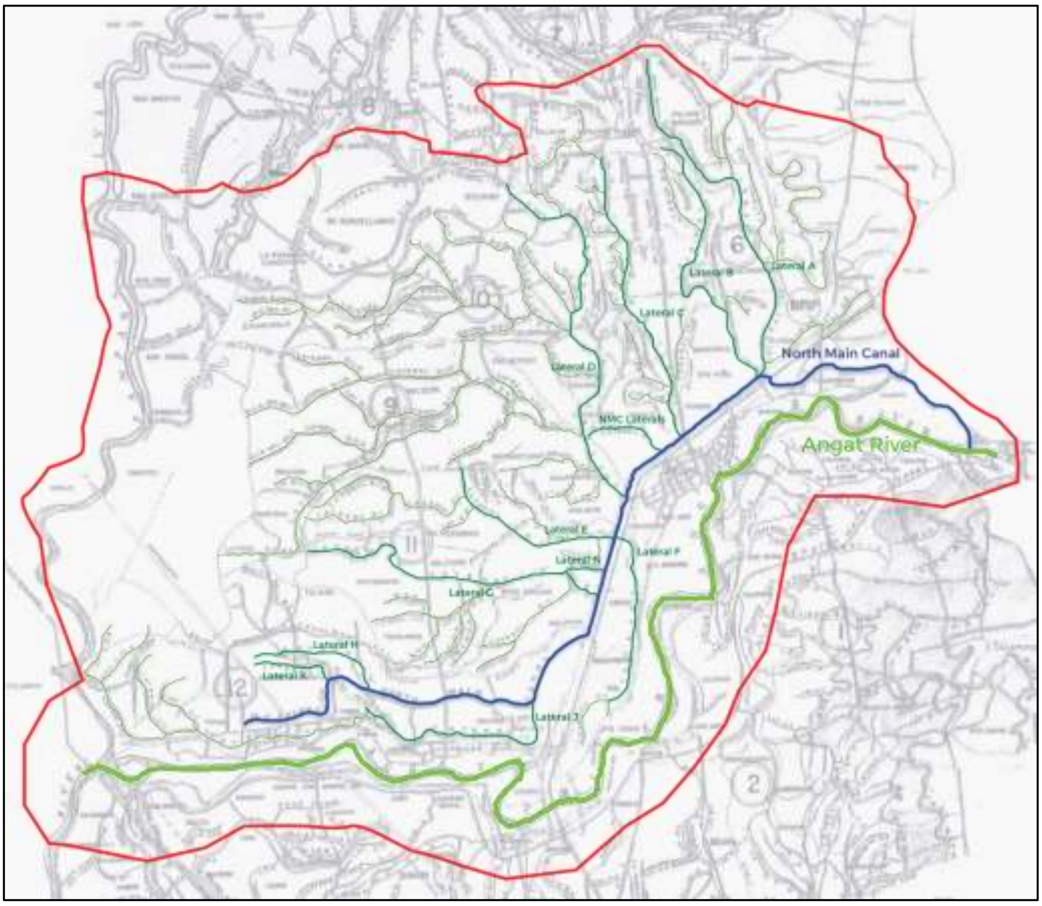


Figure 10. Sample graphical display of HEC-RAS computer model results in a particular lateral canal of the of AMRIS canal network.

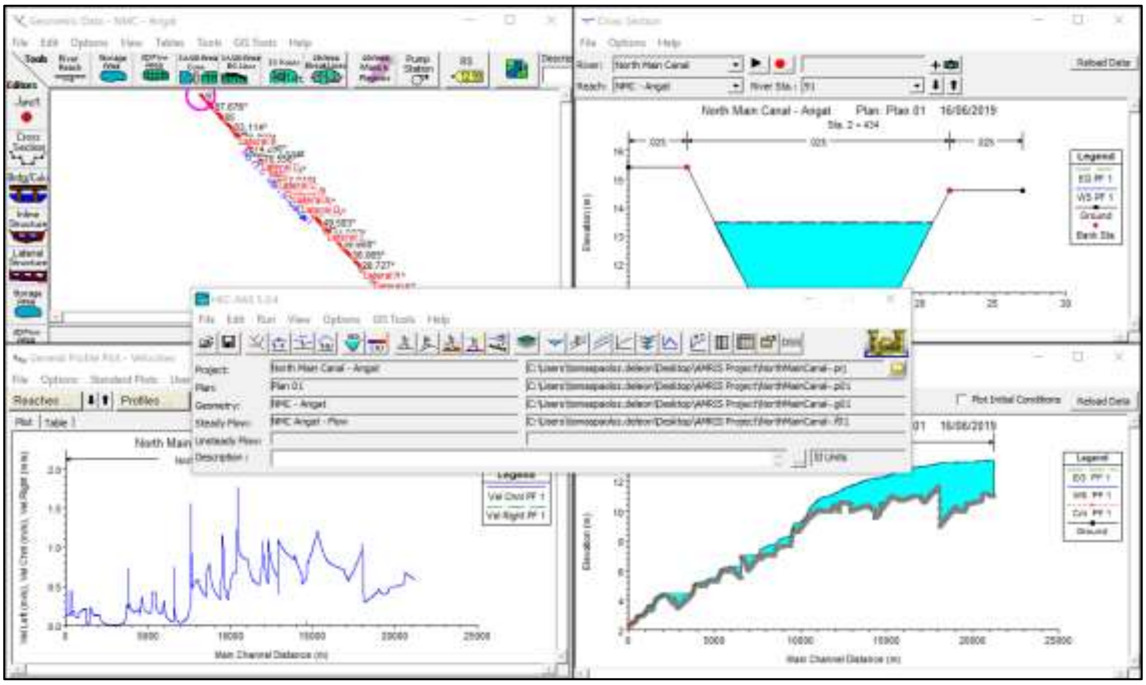


Table 3. Results of hydraulic simulation for North Main Canal with inflow of 14.6 CMS.[†]

Lateral	Stations	14.6 cms				
		Water Surface	Bank Elevation	Difference	Lateral Depth	Water Depth
Grand Total A	Sta. 6 + 480	12.81	14.3	1.49	3.7	2.21
Grand Total B	Sta. 6 + 480	12.81	14.3	1.49	3.7	2.21
Grand Total C	Sta. 8 + 987	11.95	12.7	0.75	2.6	1.85
Grand Total NMC	Sta. 9 + 770	11.78	12.9	1.12	2.5	1.38
Grand Total D	Sta. 10 + 780	11.22	13	1.78	3	1.22
Grand Total E	Sta. 11 + 715	10.61	12.6	1.99	2.2	0.21
Grand Total F	Sta. 11 + 890	10.37	12.5	2.13	2.5	0.37
Grand Total N	Sta. 12 + 264	10.33	12.4	2.07	2.4	0.33
Grand Total G	Sta. 13 + 240	9.52	12	2.48	2.5	0.02
Grand Total J	Sta. 16 + 048	7.03	9	1.97	2	0.03
Grand Total H	Sta. 20 + 080	4.92	6.1	1.18	1.2	0.02
Grand Total K	Sta. 21 + 248	4.46	5	0.54	1	0.46

Table 4. Results of hydraulic simulation for North Main Canal with inflow of 18.0 CMS.

Lateral	Stations	Flow 18 cms				
		Water Surface	Bank Elevation	Difference	Lateral Depth	Water Depth
Grand Total A	Sta. 6 + 480	13.05	14.3	1.25	3.7	2.45
Grand Total B	Sta. 6 + 480	13.05	14.3	1.25	3.7	2.45
Grand Total C	Sta. 8 + 987	12.26	12.7	0.44	2.6	2.16
Grand Total NMC	Sta. 9 + 770	12.09	12.9	0.81	2.5	1.69
Grand Total D	Sta. 10 + 780	11.68	13	1.32	3	1.68
Grand Total E	Sta. 11 + 715	11.12	12.6	1.48	2.2	0.72
Grand Total F	Sta. 11 + 890	11.05	12.5	1.45	2.5	1.05
Grand Total N	Sta. 12 + 264	10.95	12.4	1.45	2.4	0.95
Grand Total G	Sta. 13 + 240	9.83	12	2.17	2.5	0.33
Grand Total J	Sta. 16 + 048	7.12	9	1.88	2	0.12
Grand Total H	Sta. 20 + 080	4.93	6.1	1.17	1.2	0.03
Grand Total K	Sta. 21 + 248	4.47	5	0.53	1	0.47

Table 5. Results of hydraulic simulation for North Main Canal with inflow of 26.65 CMS.

Lateral	Stations	26.648 cms (Original)				
		Water Surface	Bank Elevation	Difference	Lateral Depth	Water Depth
Grand Total A	Sta. 6 + 480	13.61	14.3	0.69	3.7	3.01
Grand Total B	Sta. 6 + 480	13.61	14.3	0.69	3.7	3.01
Grand Total C	Sta. 8 + 987	12.91	12.7	-0.21	2.6	2.81
Grand Total NMC	Sta. 9 + 770	12.77	12.9	0.13	2.5	2.37
Grand Total D	Sta. 10 + 780	12.44	13	0.56	3	2.44
Grand Total E	Sta. 11 + 715	11.91	12.6	0.69	2.2	1.51
Grand Total F	Sta. 11 + 890	11.84	12.5	0.66	2.5	1.84
Grand Total N	Sta. 12 + 264	11.68	12.4	0.72	2.4	1.68
Grand Total G	Sta. 13 + 240	10.59	12	1.41	2.5	1.09
Grand Total J	Sta. 16 + 048	8.71	9	0.29	2	1.71
Grand Total H	Sta. 20 + 080	6.4	6.1	-0.3	1.2	1.5
Grand Total K	Sta. 21 + 248	6.12	5	-1.12	1	2.12

[†] In the 3 tables above, the *difference* of bank elevation and water surface at NMC is: green if positive while red if negative thus overflowing. For the *water depth* at NMC (main canal): green if above 2.5m, yellow if between 1m to 2.5m and red if below 1m. The lower the *water depth* relative to the *lateral depth*, the higher lift is required to move from main canal to lateral canal.

Figure 11. Simulated water elevations at North Main Canal with inflow of 14.6 CMS.

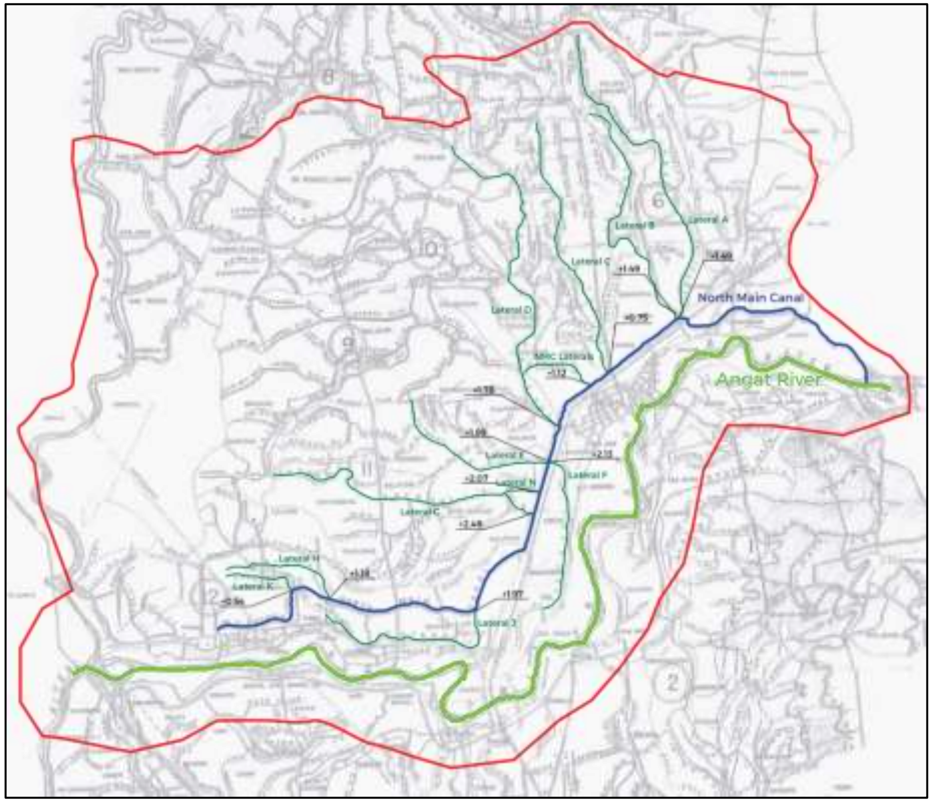


Figure 12. Simulated water depth at North Main Canal with inflow of 14.6 CMS.

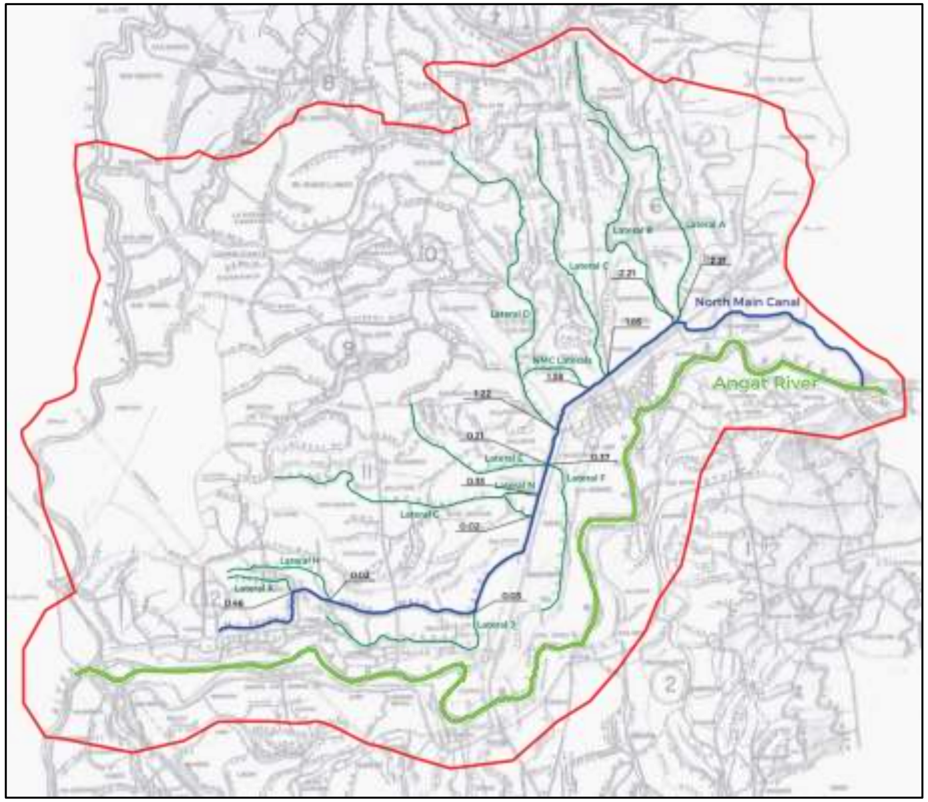


Figure 13. Simulated water elevations at North Main Canal with inflow of 18.0 CMS.

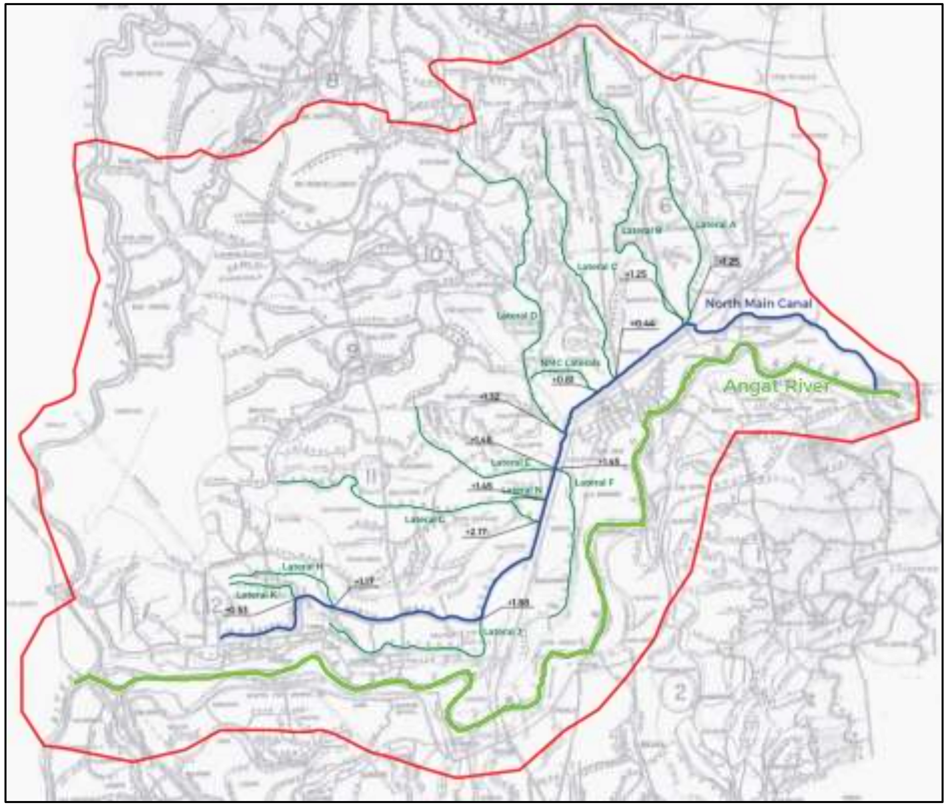


Figure 14. Simulated water depth at North Main Canal with inflow of 18.0 CMS.

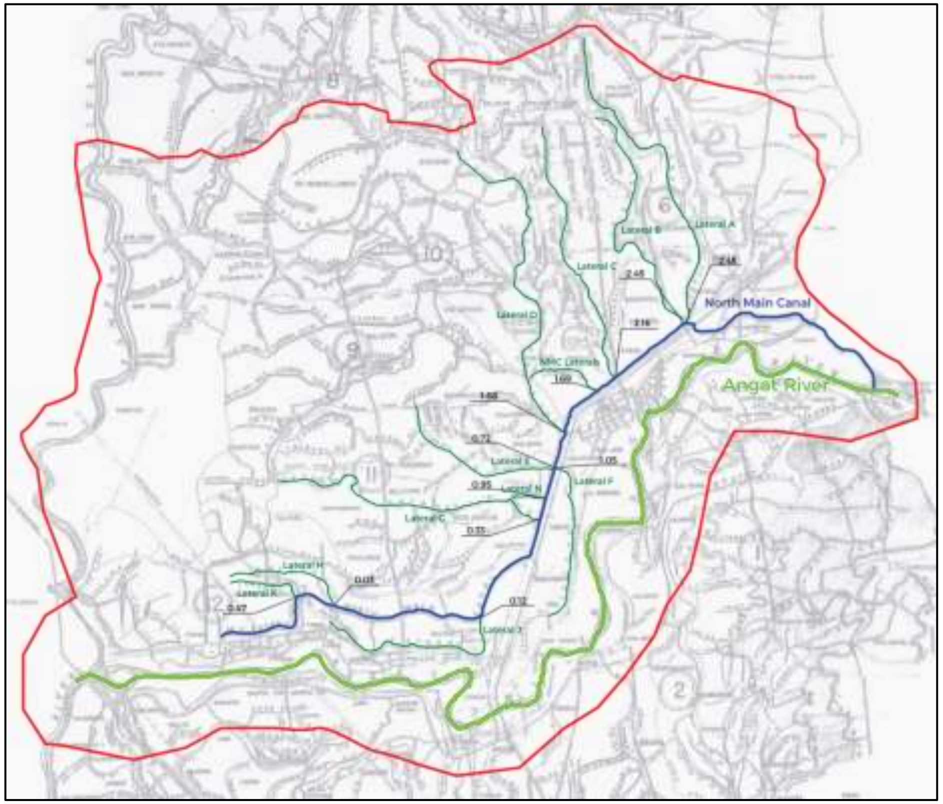


Figure 15. Simulated water elevations at North Main Canal with inflow of 26.65 CMS.

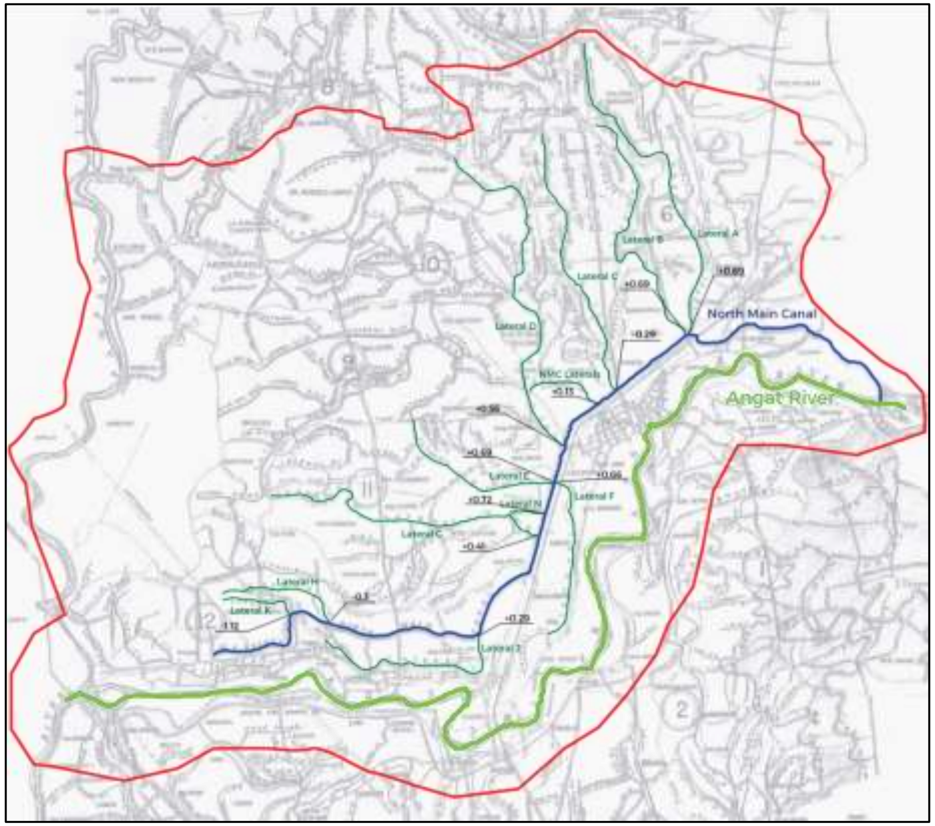
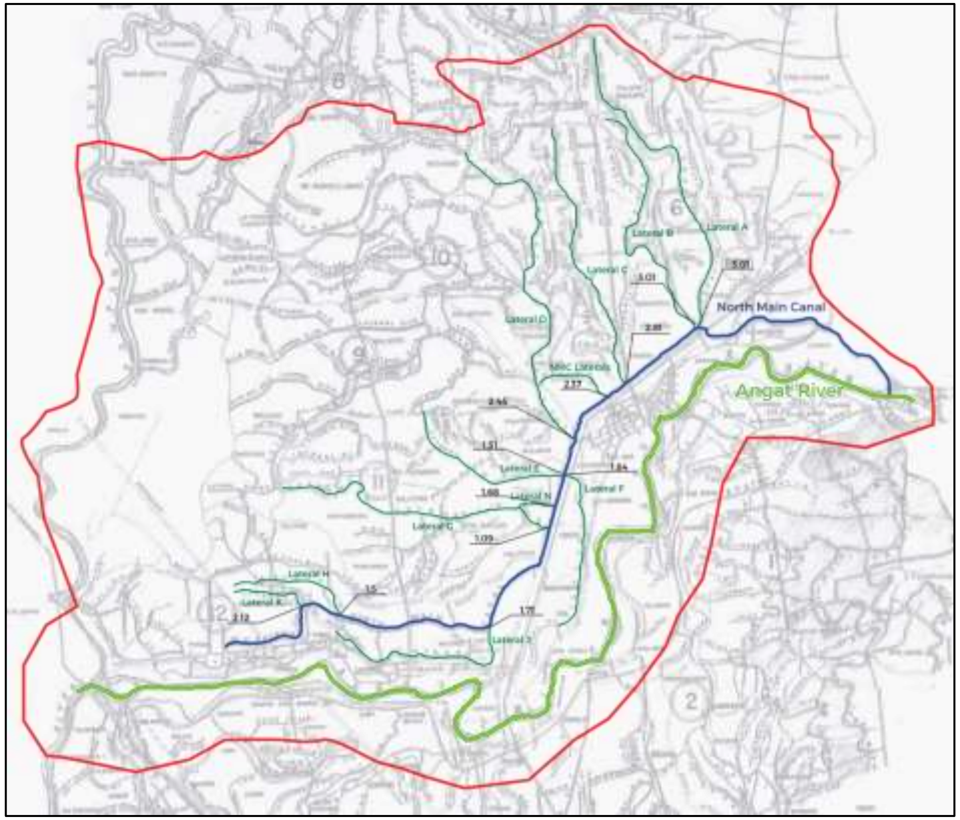


Figure 16. Simulated water depth at North Main Canal with inflow of 26.65 CMS.



5. Conclusions and Recommendations

Briefly, the objective, method of analysis and study area are summarized as follows. The main objective of this study is to assess the design irrigation service areas as originally planned compared to the actual service areas in relation to water availability, land use (including flood vulnerability) and status of irrigation facilities. The study approach or methodology is to evaluate the ability (how much) and reliability (percent-of-time available) of the water resources (water source), land resources (slope, soils and land use) as well irrigation facilities (configuration and dimension) to irrigate so much area through watershed, reservoir and irrigation distribution modeling and simulation. Two (2) national irrigation systems studied are the Angat-Maasim River Irrigation System, (AMRIS) and Pampanga Delta River Irrigation System (PADRIS).

On the basis of the objectives and method of analysis, the major conclusions based on results of this study are as follows:

1. From the original design irrigation area of NIA-AMRIS of 31,400 ha, it has now reduced to about 17,500 ha during the wet cropping season and 24,000 ha during the dry cropping season due to urbanization, lowered height of Bustos Dam thus certain areas can no longer be irrigated and some areas are flooded during the wet season. This resulted in the decision of the NWRB to reduce the Angat water allocation to irrigation from 36 to 22 CMS in which the difference of 15 CMS is unused water of NIA-AMRIS and was re-allocated to MWSS for domestic water supply (referred conditional water right of MWSS as early as 1988).

2. With the above changes in physical conditions that limit the irrigation service area of AMRIS and together with the reduced Angat water allocation to irrigation, it should be recognized and accepted that this is the current status of AMRIS as an irrigation system. However, there is still the complicating issue of competing water use with hydropower since the 200 MW plant of SMC/K-Water is through NIA-AMRIS irrigation water releases compared to its 18 MW hydropower plant through the MWSS domestic water releases.

3. The PADRIS system has likewise only realized half of the target irrigation service area from originally planned service area of 11,540 ha due to urbanization and flooding problems as well as issue with the height of Cong Dadong Dam as described below. In the last few years, PADRIS only irrigated about 7,000 ha during the dry cropping season and 5,000 ha during the wet cropping season. While the irrigation water available from Pampanga River through the Cong Dadong Dam (diversion structure) is not limiting, the diversion dam height of 8.6 m is not high enough so it is unable to irrigate over 2,000 ha of the target irrigation service area.

4. In this study, only the AMRIS irrigation canal network was investigated through hydraulic modeling and simulation since geometry data of the canal network is available. However, since there was no geometry data of the PADRIS canal network, no hydraulic simulation was conducted. In any case, there was no available or operational hydraulic model for either the AMRIS or PADRIS irrigation canal network which definitely would be useful for operational studies or for real-time operations. For the AMRIS canal network simulations, it was shown that there are areas that may not

at all be irrigated since most canals had reduced capacities due to sedimentation, consequently the channel slopes or gradients needed for gravity flow is no longer efficient. Thus, there is a need to develop effective canal maintenance scheme of the AMRIS and also to reassess the operation schemes for efficient canal operations.

The following are major recommendations in this study:

1. The irrigation water supply to AMRIS from Angat Reservoir (including contribution from Bustos watershed) may be curtailed due to episodic occurrences of critical dry years associated to Pacific Equatorial anomalies such as El Nino. It can also be constrained due to competing water uses with domestic water supply which has higher release policy during low Angat Reservoir water levels or equivalently, water shortage conditions. Although the AMRIS irrigation water demand has reduced in the last 20 years or so, the irrigation water requirement of AMRIS is still significant especially during the dry cropping season period of December to March which coincides during the onset of the dry season when the Angat Reservoir should be filling-up or saving water for the dry months of April and May. It is recommended that the dry and wet cropping season schedules should be revisited to maximize its conjunctive use of Angat watershed streamflow (through the reservoir) with the seasonality of rainfall to minimized its competing use with Metro Manila's water supply demand which is fixed and uniform all year round.

2. Water supply to PADRIS is not at all limiting since there is more than enough flowing from the Pampanga River at the point of diversion. The only constraint is that the diversion dam elevation is not high enough to cover the entire design service area of PADRIS thus over 2,000 hectares cannot be irrigated. A recommendation is to possibly heighten the diversion structure of PADRIS and the economics of this should be carefully considered.

3. Both AMRIS and PADRIS have reduced irrigation service area from originally planned due to urbanization and flooding problems, as well as technical issues. In the case of urbanization in the AMRIS area, a significant portion of the agricultural land was converted to industrial and/or residential developments being near to Metro Manila. Urbanization has also taken toll of the agricultural areas in PADRIS being adjacent to the growing metropolis development of New Clark City and San Fernando City of Pampanga. With regard to flooding problems, both AMRIS and PADRIS have low lying areas in their lower ends being in the vicinity of the Pampanga Delta, there is not much can be done to encourage the rice farmers to plant rice during the wet season.

4. In AMRIS, the canal network simulation studies of irrigation water flows show that there are areas that may not at all be irrigated due to canal shallowing because of sedimentation. Consequently, the channel slopes needed for gravity flow are no longer efficient. It is definitely worthwhile to properly mitigate the sedimentation problem and also design the canal maintenance with dredging or rehabilitation based on optimally satisfying both the slope and canal width/depth including alignment requirements. This type of analysis and operations studies can only be done through canal network model simulation studies.

5. It cannot be overemphasized that periodic operational studies once the system is already built are crucial to make adjustments based on actual observations and experiences. Likewise, periodic assessment, at least every 3 years, the efficiency of irrigation water delivery operations should also be conducted for proper maintenance and upgrade of irrigation facility, if needed This is illustrated in this study through hydraulic model simulations which should be conducted for proper maintenance and upgrade of irrigation facility as needed. Of course, the importance of developing and maintaining an operational hydraulic model of the irrigation canal network cannot be overemphasized which is definitely useful for operational studies or real-time operations of the AMRIS or PADRIS.

6. Finally, a review of the feasibility studies (reports) of these irrigation systems showed that it seem lacking in detailed technical assessment of performance of the irrigation systems with regard to reliability of water sources (in time and space), simulation of hydraulic performance of canal system, for example, under “dry year” or under “flooding” conditions. Thus, reassessment of the details of the operations should be done.

7. Bibliography

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