Flood Based Tidal Irrigation System in Delta Area of Myanmar

19

Overview paper

META

Flood-Based Livelihoods Network Foundation

SEPS

Flood-Based Livelihoods Network Myanmar

ABSTRACT

Flood Based Tidal Irrigation System in Delta Area of Myanmar

The flood-based systems in the Ayeyarwady Delta Area, dual-purpose canals, were designed and constructed for irrigation as well as drainage. At the end of monsoon season, usually in November and December flood water in the canal is controlled by sluice gates to raise water level so as to irrigate adjacent areas by gravity and stored in the paddy fields by earthen bunds. River water level rises up due to tidal effect and this level is higher than the ground level of irrigable area. During high tide level, fresh water from the river is supplied by the canals through the sluice gates. In Ayeyarwady region near Yangon, one tidal irrigation system was implemented near Pan Hlaing River and successfully irrigating about 8,000 hectares of summer paddy land and fish ponds. The sluice serves for dual purpose-discharging polder water into the river during November to December and irrigating river water during spring tide in January to April. Just like spate irrigation, river water can be supplied in a few hours during high tide periods. Therefore sluice and canal sizes are comparably large to conventional irrigation system.

1. INTRODUCTION

Myanmar is the largest country in mainland Southeast Asia with a land area of about 654,000 square kilometers, abundant natural resources and one of the lowest population densities in the region. Its geographic location is between China, India and Thailand and more than 2,800 kilometers of coastline. It is well positioned to resume its traditional role as regional trading hub and key supplier of minerals, natural gas and agricultural produce.

Myanmar is a land and water rich country. It has the world's 25th largest arable land area and 10 times the per capita water endowment of China and India. It was once the world's largest rice exporter.

The Ayeyarwady is Myanmar's largest river basin and has been described as the heart of the nation. It is a river of global proportions, with an average annual flow equivalent to roughly 85% of the Mekong. Groundwater resources in the basin are believed to be even greater than surface water resources.

It is one of the most important regions of the Union of Myanmar from the economic point of view and the soils in the area can be considered as the richest ones of the country ("Rice bow" of Myanmar). The density of population is greater than in other parts of the Union, with population density of 230 inhabitants/km^2.

The delta covers an area of about 35,000 square km., having a maximum width of about 200 km. and a maximum length of about 290km. It is a flat and fertile alluvial plain, interwoven with rivers and creeks.

The delta region is densely populated and plays a dominant role in the cultivation of rice in rich alluvial soil as low as just 3 meters above sea level. It also includes fishing communities in a vast area full of rivers and streams. It is mainly populated by farming and fishing communities in several villages besides market towns, mostly located along the main rivers.

The discharge in the Ayeyarwady River is at its lowest in February and March and there is a sharp rise in April-May as a result of melting snow in the upper catchment, followed by a further steep rise in May-June with the onset of the monsoon. The maximum flow occurs in July or August.

The tidal variation shows a distinct pattern of spring and neap tides. The tidal influence enters deep into the delta, which offers opportunities for tidal irrigation. The sluice is located in fresh water zone of the area as shown in figure1 and 2.

Tidal irrigation during the dry season is extensively practiced in the middle delta, while in the upper delta irrigation takes place by gravity or pumping.

It was designed and implemented, as the first of its kind in Myanmar for the dual purpose of drainage and summer paddy irrigation and fish ponds by installing double flap sluice gates on both sides of the structure. Flood water of one foot depth is usually controlled and stored in the paddy field in December by earthen bunds for land preparation. It is a kind of Integrated Water Resources Management and also supports food security of local area, including Yangon City.

2. STUDY AREA

The Pan Hlaing sluice is situated on the bank of Pan Hlaing River, near Sa-Malauk Village, Nyaungdon Township, Ayeyarwady Division. It was built to reduce the flooding on the area of Nyaungdon in the rainy season, and to distribute water for summer paddy and fish ponds during dry season.

Nyaungdone Island is in Ayeyarwady Division and composed of Nyaungdone Maubin Townships. It is surrounded by Ayeyarwady River, on the west, Khattiya Yaykyaw Creek on the east, Pan Hlaing River, on the north and Toe River on the south.

Pan Hlaing sluice is located near mile 28/3 of Yangon-Nyaungdon Highway Road.

Location and Canal Network of Pan Hlaing sluice in Nyaungdone Island are shown in figure (2).

Location of downstream side of Pan Hlaing sluice, with 25 numbers of 4' diameters concrete pipe, with flap gates on both sides are shown in figure (3).

Except south east portion where there is salt water, the whole island is surrounded by fresh water channels and rivers of abundant water resources.

3. IRRIGATION TECHNOLOGIES

3.1. Reference Crop Evapotranspiration (ET_0)

The reference crop evapotranspiration (ET_0) is estimated by using Cropwat 8.0 software based on FAO Penman-Monteith Method. The FAO Penman-monteith Method has been recommended as the appropriate and sole standard method

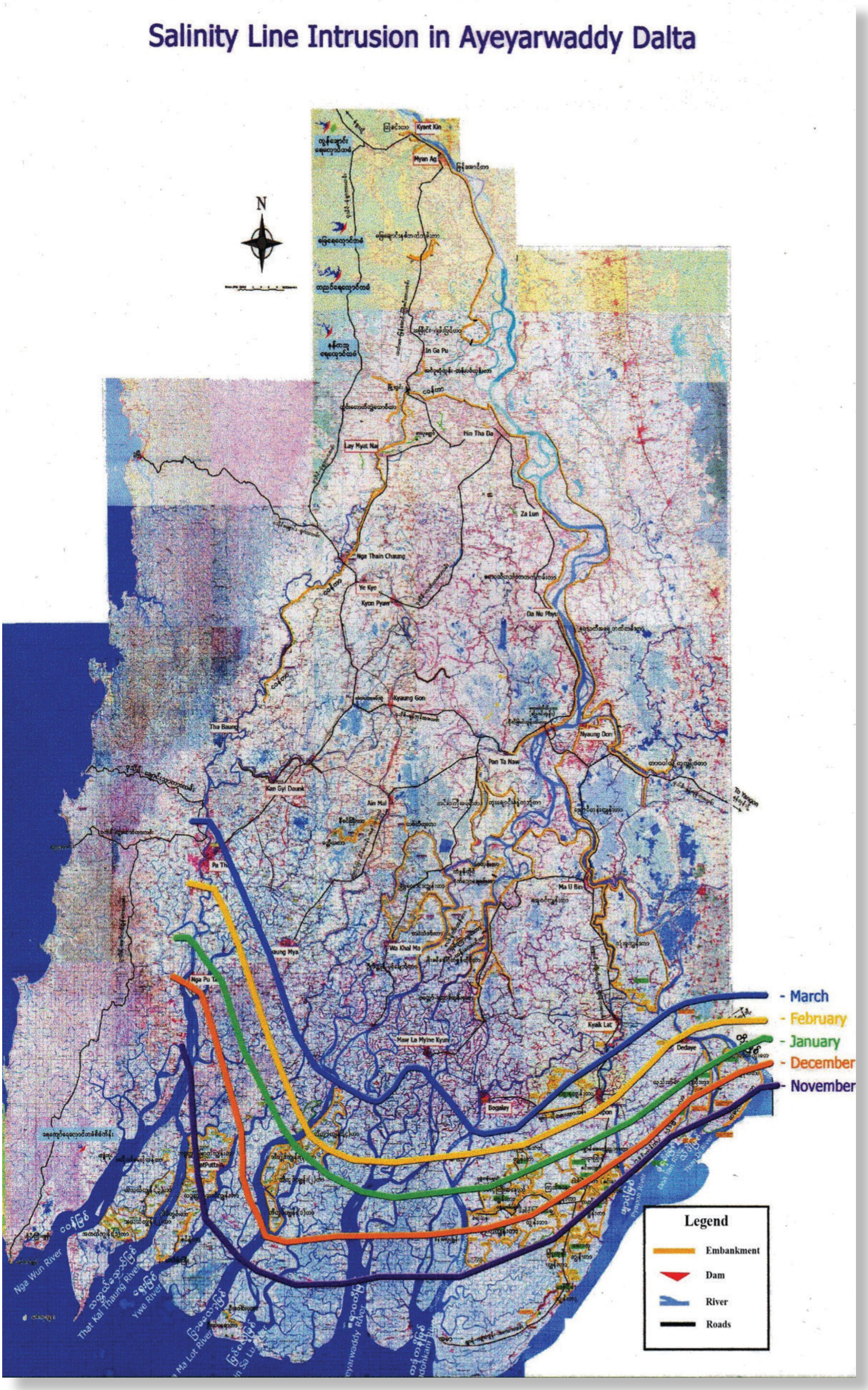

Figure (1) Salinity line intrusion in Ayeyarwady Delta (1 ppt). Source: Irrigation Department (ID 2013)

Table (1) Results of Reference Crop Evapotranspiration

Year	ET_o (mm/day)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2009	3.49	3.92	4.51	4.79	4.02	2.77	2.60	3.02	2.89	3.32	3.90	3.48
2010	3.54	4.32	4.49	5.80	4.98	3.24	3.33	2.89	3.18	3.47	4.16	3.63
2011	3.53	4.40	4.27	4.98	3.71	2.95	3.07	2.76	2.77	3.45	3.93	3.65
2012	3.75	4.14	4.60	5.28	3.92	2.97	2.71	2.63	3.21	3.78	3.56	3.64
2013	3.71	4.55	5.09	5.68	4.46	3.03	2.77	2.88	2.91	3.55	3.95	3.30
2014	3.70	4.09	4.96	4.88	4.34	2.88	2.52	2.73	2.88	3.75	3.47	3.71
2015	3.56	4.08	5.05	5.54	4.62	3.32	3.01	2.79	3.23	3.32	3.97	3.63
2016	3.66	4.04	4.48	5.10	4.41	2.94	2.79	2.82	2.95	3.12	3.85	3.64
2017	3.60	4.26	4.91	4,74	4.06	3.08	2.53	2.62	3.22	3.17	3.43	3.61
2018	3.41	4.01	4.39	4.99	4.24	2.87	2.43	2.51	3.27	3.38	3.77	3.34

Figure (2) Location and Canal Network of Nyaungdon Island – Pan Hlaing Sluice: Source: ID (2013 b)

(Reference; to FAO Irrigation and Drainage paper 56) To calculate ET_0, monthly meteorological data are collected from 2009 to 2018 from Kaba-Aye Station. These data included maximum air temperature, minimum air temperature, relative humidity, sunshine hour, surface wind speed and rainfall. The reference surface is a hypothetical grass reference crop with specific characteristics.

The only factors affecting ET_0 are climatic parameters. Consequently, ET_0 is a climatic parameter and can be computed from weather data. ET_0 expresses the evaporating power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors.

3.2. Effective Rainfall

There are four methods to calculate effective rainfall such as fixed percentage of rainfall method, dependable rainfall method, empirical formula and USDA soil conservation service method. Unless more detailed information is available for local conditions, it is suggested to use "Fixed percentage" method. In general, the efficiency of rainfall will decrease with increasing rainfall. Therefore, fixed percentage of rainfall method is selected in this study and the effective rainfall is 80%. Generally for summer paddy, rainfall is very small and neglectable.

The results of monthly effective rainfall from 2009 to 2018 are described in Table (2).

Planting period is expected to be from first week of January to second week of April for 100 days planting period. Nursery plantation has to be carried out in other suitable places in December, where flood water is stored in earthen bund. Summer irrigation water supply will usually start in first week of January.

Figure (3) Downstream Side of the Pan Hlaing Sluice

Table (2) Results of Monthly Effective Rainfall

Months	Effective Rainfall (mm)									
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
January	0	0	38.4	0	4.8	0	0	18.4	0.8	0
February	0	0	0	0	0	0	0	0	0	0
March	4	0	102	0	0	0	7.2	0	0	0
April	36.8	0	4	6.4	0	0	32	0	64.8	33.6
May	366	246	330	134	100	236	148	230	360	207
June	449	423	449	360	445	561	464	309	520	502
July	731	294	459	574	504	654	554	494	642	645
August	388	374	492	691	371	460	326	421	306	462
September	406	322	430	303	490	158	263	434	321	378
October	100	294	142	55.2	297	179	284	182	297	183
November	0	5.6	0	92	10.4	240	55.2	0.8	100	56
December	0	26.4	0	1.6	2.4	20.8	0	0	0	48.8
Total	2481	1984	2446	2217	2224	2509	2134	2090	2610	2515

3.3. Crop Evapotranspiration (ETc)

The crop evapotranspiration under standard conditions, denoted as ETc, is the evapotranspiration from disease-free, well-fertilized crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions (FAO 56). There are several crops planting in Nyaungdon Township. However summer paddy and monsoon paddy are mainly planted in the area. Soil type of this area is mostly clay soil. Effective rainfall is considered as fixed percentage (80%) of total rainfall. The growing period is 100 days for summer paddy.

The crop evapotranspiration can be obtained by multiplying the reference crop evapotranspiration with crop coefficient.

$ETc = Kc \times ET_0$

Where,

ETc = crop evapotranspiration [mm/day]

Kc = crop coefficient [dimensionless]

ET_0 = reference crop evapotranspiration [mm/day]

The results show that the maximum crop water requirement (ETc) for summer paddy is found in March as shown in Table 3.

Table (3) Results of crop water requirement for summer paddy

Year	ETc (mm/dec)			
	Jan	Feb	Mar	Apr
2009	119.1	124.3	163.7	127.4
2010	122.3	133.6	164.3	151.1
2011	119.9	137.4	156.9	130.0
2012	127.4	130.6	167.8	139.2
2013	126.7	143.5	189.4	154.4
2014	126.0	131.2	181.5	129.8
2015	122.1	130.6	183.8	147.1
2016	124.4	127.4	163.3	134.1
2017	123.6	133.9	174.8	124.3
2018	116.7	125.9	161.3	131.6

The crop water requirement for summer paddy is highest in March (31days). The maximum value of crop water requirement (ETc) is 189.4 mm/month (7.5 in/month) for March. Therefore, total crop water requirement for March is 13.7 in/month (1.14ft) by adding percolation loss (5mm/day or 6.2 in/month).

Table (4) Irrigation Water Requirements for Summer Paddy

Year	IWR (mm/dec)
	Summer Paddy
2009	770.9
2010	822.3
2011	662.3
2012	823.6
2013	865.2
2014	596.7
2015	815.5
2016	792.5
2017	780.4
2018	758.2

3.4. Irrigation Water Requirement

Irrigation water requirement is defined as the crop water requirement plus percolation loss and minus the effective rainfall. After determining crop evapotranspiration (ETc) and effective rainfall, the result of irrigation water requirement for summer paddy according to CROPWAT 8.0 Software is described in the above Table 4.

3.5. Irrigation Efficiency

Soil type of the study area is black clay and so the conveyance efficiency is taken 0.8. Operation efficiency is taken as 0.9 as all the canals in the study area unlined canal. Irrigation water is supplied to the crops by the surface irrigation method and thus, application efficiency is assumed as 0.8.

Project Efficiency $Ep = Ea \times Eb \times Ec = 0.8 \times 0.9 \times 0.8$

$= 0.58$ say 0.6

4. TIDAL IRRIGATION SYSTEM

4.1. General Features

The Tide is the regular periodic rise and fall of the surface of the oceans. Tides are related to the attractive forces of the sun, moon and earth in the solar system.

In Ayeyarwady Delta, There are mainly two types, spring tide and neap tide. Spring tides occur 2 times a month, during a full and new moon when the Earth, Sun and Moon are lined up.

Neap tides occur in between spring tides.

The tidal variation shows a distinct pattern of spring and neap tides. The tide influence enters deep into the delta, which offers opportunities for tidal irrigation.

At the end of monsoon season, the saline water front begins to intrude as the river discharge falls. Usually one thousand parts per million or one part per thousand (1 p.p.t) salt water intrusion lines is necessary for selection of intake sluice structure site. The pattern of saline water intrusion for Ayeyarwady River Delta is shown in figure (1).

In Ayeyarwady delta area, sediment deposits from recurrent river flooding, have made the islands slightly saucer shaped, higher at the edge and sloping towards the center. Therefore, it is favorable for tidal gravity irrigation system in fresh water zone of Ayeyarwady Delta area. In polders a rain fed network, of drainage canals, is required and it is economical to use the same network for irrigation purposes.

4.2. Design tide Curve for tidal irrigation

A stylized design tide curve is necessary to construct for required month by the following method as shown in Table (5).

Where H.T.L = High tide level

L.T.L = Low tide level

M.T.L = Mean tide level

X = (HTL – LTL)/10

Table (5) Stylized design tide curve method

TIME (Hrs)	LEVEL (ft)
0	H.T.L
1.5	(HTL + MTL) /2 + X
3.0	M.T.L
4.5	(MTL + LTL) /2 – X
6.0	L.T.L
7.625	(MTL + LTL) /2 – X
9.25	M.T.L
10.875	(HTL + MTL) /2 + X
12.5	H.T.L

The design of a tidal irrigation system as a matter of fact is the reverse of that for a drainage system, one major difference being the downstream boundary conditions. The following steps are the method of construction of synthetic design tide curve.

1. From the recorded data, average High Tide Level (H.T.L), Low Tide Level (L.T.L) and Mean Tide Level (M.T.L) are calculated. On a graph paper, make horizontal as time scale and vertical as height of tide level.
2. Make on graph paper the point of H.T.L, M.T.L and L.T.L. Then draw a straight line passing through these points.
3. Divide from equal distance points in these lines, and points are important in drawing tide curve.
4. Draw a line perpendicular to upward from the ¼ point nearest to H.T.L. Draw another line perpendicular to downward from ¼ point nearest to L.T.L. The length of the perpendicular line is 1/10 of the difference of H.T.L and L.T.L.
5. Based on the above H.T.L, M.T.L, L.T.L and, as mentioned above intermediate point, draw a smooth tidal curve. This tidal curve will represent the design tide curve. Method of Construction of Stylized Design Tide Curve is shown in Table (5).

March is critical month for irrigation. The tide water levels in March are collected for five year (from 2014 to 2018) from Irrigation Department of Maubin. After analyzing the data of river gauge, about fifteen days per month can apply irrigation water during summer period. The results of average maximum and minimum tide water level in March are shown in Table (6).

Reference: Tide table for Myanmar Coastal area by Myanmar Navy

Table (6) Results of Average Tide Level for March

Year	Average Maximum Water level (ft)	Average Minimum Water Level (ft)
2014	6.8	1.5
2015	7.1	0.8
2016	7.9	2.1
2017	7.7	2.2
2018	7.9	2.0
Avg. W.L.	7.48	1.72
Design W.L.	7.5	1.7

The total irrigation period of critical month is taken as fifteen days for a month, based on recorded water levels. The high tide level (H.T.L), Low tide level (L.T.L) and mean tide level (M.T.L) are calculated based on tide water level. A stylized design tide curve is constructed by the following method as shown in Table (7).

Table (7) Method of Stylized Design Tide Curve

Time (hours)	Water level (ft)	
0	H.T.L	=7.5
1.5	H.T.L+M.T.L)/2 + X	= 6.63
3.0	M.T.L	= 4.6
4.5	M.T.L+L.T.L)/2 – X	= 2.57
6.0	L.T.L	= 1.7
7.625	(M.T.L+L.T.L)/2 – X	= 2.57
9.25	M.T.L	= 4.6
10.875	(H.T.L+M.T.L)/2 + X	= 6.63
12.5	H.T.L	= 7.5

H.T.L =7.5ft, L.T.L = 1.7 ft M.T.L = 4.6 ft

X = (H.T.L – L.T.L) / 10

= (7.5 – 1.7) / 10

= 0.58 ft

4.3. Calculation of Discharge of one Spring Tide

The calculation of discharge for one high tide (spring tide) is based on stylized design tide curve as shown in figure (4). The downstream water level of main canal fluctuates from 4.5 ft to 5.0 ft during high tide. The discharge of sluice in the region varies with tide level outside and water level inside the canal. The actual hydraulic condition is unsteady flow condition. The discharging period is sub-divided into small interval of 30 minutes for steady flow condition. After the upstream and downstream water level is fixed, the discharge through a sluice is calculated by applying totally submerged flow condition. The sill level of 4 ft diameter concrete pipe is fixed at RL 0.0 ft for both intake and discharging cases. Number of days to be irrigated is taken as 15 days per month during spring tide with irrigation period of 6 hours per high tide. The discharge for each small period of 0.5 hours is calculated for each flow condition. The coefficient of discharge is taken as 0.7 for socket end concrete pipe. The calculation of discharge of spring tide is described as follow;

Discharge, $Q=Cd\ A\ \sqrt{2gz}$

Where,

Q = discharge (cusec)

Cd = discharge coefficient (taken as 0.7)

Z = head difference between tide water level and upstream water level (canal water level)

A = area of pipe (ft^2)

As a result, maximum discharge of one high tide period is 116 cusecs. The average discharge is 89 cusecs and the total volume of water is 44.11 acre-ft. The results of calculation of discharge for each small period are shown in Table 8.

Table (8) Result of Discharge and Inflow for March for one spring tide (high tide)

Time (hour)	Sub z(ft)	Cd	Q (cusec)	T (sec)	Inflow (acre-ft)
0	-	-	-	-	-
0.5	0.6	0.7	54.68	1800	2.26
1	1.2	0.7	77.33	1800	3.19
1.5	1.8	0.7	94.71	1800	3.91
2	2.1	0.7	102.29	1800	4.23
2.5	2.5	0.7	111.61	1800	4.61
3	2.7	0.7	116.00	1800	4.79
3.5	2.7	0.7	116.00	1800	4.79
4	2.5	0.7	111.61	1800	4.61
4.5	2.1	0.7	102.29	1800	4.23
5	1.5	0.7	86.45	1800	3.57
5.5	0.8	0.7	63.14	1800	2.61
6	0.2	0.7	31.57	1800	1.31
Total			1067.66		44.11
Average			88.97 = 89		

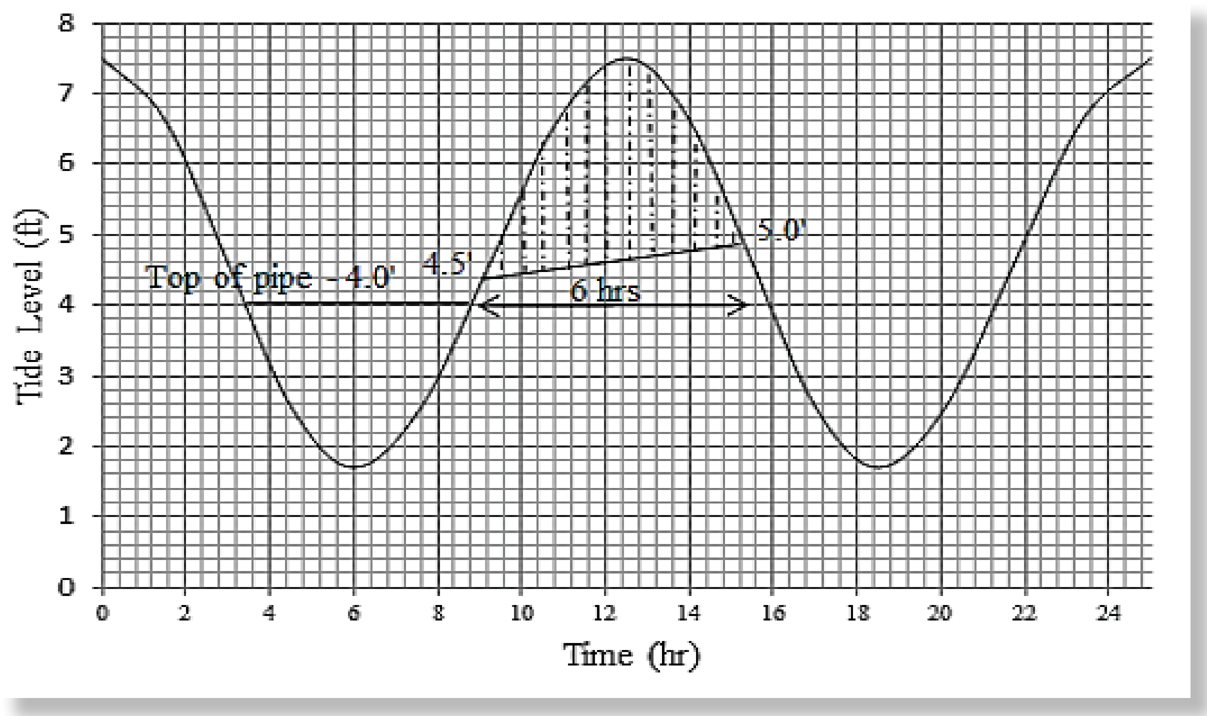

Figure (4) Stylized Design Tide Curve for March

4.4. Calculation of Irrigable Area

The calculation of irrigable area is based on total inflow of 25 numbers of openings of the sluice. For one spring tide, the total inflow is 44.11 acre-ft from the design tide curve. Irrigation rotation is 2 spring tides per month. One spring tide is 7.5 days for 2 times a day. The overall efficiency is used 60% with water requirement of 1.14 ft depth of water. The tidal irrigation is benefited about 17000 acres of summer paddy and three thousand acres of fish ponds. The calculation of irrigable area is described as follow;

Volume of water for March = 44.11 x 2 x 2 x 7.5 x 25

= 33082.5 acre-ft

The irrigable area = 33082.5 x 0.6

= 19849.5 acre-ft/1.14 ft

= 17411 acres say 1700

Total benefitted area will be about 20000 acres including 3000 acres of fish ponds.

4.5. Design of Irrigation Canal and Out-fall channel

The calculation of irrigation canal is based on water level in March and existing number of openings of the sluice. The canal is open channel type and it is an earthen channel. The cross-section shape is trapezoidal. The length of main canal is two miles. The maximum discharge of one opening is 116 cusec from the table (8). The total discharge of the sluice is 2900 cusecs for 25 opening. The canal side slope is 1.5:1 and coefficient of roughness is taken as 0.0225. The bed slope of canal is 0.00015. The depth of water is 5 ft and the bed width of the canal is calculated by using Manning's formula. The calculated canal bed width is 250ft. After the sluice was completed in 1995, distributary and minor canals were constructed about 78 miles for water distribution purpose. Field channels were also constructed with farmers' participation.

4.6. Calculation of Outfall Channel

The outfall channel is calculated based on water level in December and existing number of openings of the sluice. During rainy season, river water level is higher than water level in the polder. Therefore, the sluice is discharging polder water into the river during November to December. The length of outfall channel is 750 ft. The maximum water level in December is 8 ft as per data. The maximum discharge of one opening is 173 cusecs. The total discharge of the sluice is 4323 cusecs. The canal side slope is 1.5:1 and coefficient of roughness is taken as 0.025. The bed slope of canal is 0.00016. The bed width of channel is calculated by Manning's formula and found to be 180 ft.

5. DISCUSSIONS, CONCLUSION AND RECOMMENDATIONS

5.1. Discussions and Conclusion

Considering the many issues in the Ayeyarwady Delta, and the fact that most of these issues are related to each other, Integrated Water Resources Management (IWRM) is of the utmost importance in the development strategies for the delta area. Good understanding and analysis of the problem is essential before addressing possible solutions. An integrated approach includes evaluation of the complete river basin (including upstream areas), entire production chains and the relation between water, food and energy security.

Agriculture is traditionally a very important driver for the Myanmar economy. Although the Ayeyarwady Region occupies only 5 percent of all national land in the Union, it is known as the rice bowl of the country as it produces most of the rice requirements of the country.

Tidal irrigation during the dry season is extensively practiced in the middle delta, while in the upper delta irrigation takes place by gravity or using small pumps. There are also several special polder areas where irrigation water is conveyed from the intake of the upstream reach of the tidal river where the water is fresh and free from salt water contamination. The total benefitted area about 20000 acres of summer paddy and fish ponds are supporting food security. The sluice can sufficiently supply the water required for irrigation in the area at present.

5.2. Recommendations

The World Bank has initiated the development of Ayeyarwady Integrated River Basin Management Plan (AIRBMP). The delta is one of the elements in this AIRBMP.

The increase of the rice production in the Ayeyarwady Delta got an important boost in the period 1976-1988 with the implementation of the Paddy Land Development Projects, Paddy 1, Paddy 2 (World Bank Projects). The projects consisted mainly of the construction of polders in the lower and middle delta provided with embankments, sluice gates and drainage systems, hence protecting the land from salt water intrusion.

As the average annual rainfall can be more than 3,000 mm and concentrated in the rainy season from May to October, no irrigation is practiced for rainy season paddy cultivation in the area. At the end of the monsoon season the fresh rainwater is stored in the drainage canal for irrigation, livestock and miscellaneous purposes for the dry season.

The above mentioned area of Paddy 1 and Paddy 2 are already protected from flood and salt water intrusion. Therefore, it is suggested to carry out pre-feasibility studies for Flood based tidal irrigation system projects for summer paddy and other crops.

Technical, environmental, economic and social feasibility, costs and benefits have to be taken into account when choosing between different solutions. Soil and geological testing has to be carried out for foundation investigation and design.

In the Ayeyarwady Delta saltwater intrusion is threatening drinking water resources on a large scale and is therefore confronting the population with a serious health issue. Water Safety Plans need to be updated and upgraded taking into account this new challenge of water contamination issues such as arsenic and bacterial contamination. The result of these pre-feasibility studies could subsequently be taken on by local, regional or international financing agencies.

During summer times, transportation of boat for farmers is available to travel various places including paddy field sites. Navigation depth of 5 ft is maintained in the irrigation canal by opening and closing of sluice gate by Irrigation Department Staff. Therefore it supports transportation of farmers and villagers. Therefore, this kind of work should be carried out wherever feasible in Ayeyarwady Delta, for food security and supports transportation.

Appropriate technology has to be used in design and implementation of the works. Operation, maintenance and water distribution works, should be carried out with Water Users Groups (WUG), departmental authorizes, and other stakeholders.

Capacity building needs on all levels: building at farmers' level, government from national to local, education on vocational and university level.

6. REFERENCES

FAO; Global Water Partnership 2013 Vulnerability and Resilience Assessment, Ayeyarwady Delta, Myanmar: Delta Alliance Report.

FAO Irrigation and Drainage Paper No.56

FAO. 1977. Crop Water Requirements : Irrigation and Drainage Paper No.24. Food and Agricultural Organization of the United Nations.

FAO, 1989. Irrigation Scheduling: Irrigation Water Management Training Manual No.4. Food and Agricultural Organization of the United Nations.

Halcrow, S.W. 1980. Irrawaddy Delta Hydrological Investigations and Delta Survey. Ministry of Agriculture and Forests (Burma) Irrigation Department.

Irrigation Department. 2014. Report on Pan Hlaing Sluice in Myanmar Language. Ministry of Agricultural and Irrigation.

Maung Maung Htay. 1993. Design Calculations and Drawings of Pan Hlaing Sluice. Ministry of Agriculture, Livestock and Irrigation.

Maung Maung Htay .1987. Technical Report on Tidal Gravity Irrigation System in Thongwa Island Ayeyarwady Division. Ministry of Agricultural and Forests Irrigation Department.

Myanmar Navy: 1984: Myanmar tide table for Coastal Area.

Smith, M. 2016. Example of the Use of CROPWAT 8.0. Food and Agricultural Organization of the United Nations.

U.S Department of Agricultural: Soil Conservation Service: 1971. National Engineering Hanbook-Drainage of Agricultural Land

Volker, A.1974. Reclamation and Polders Lecture Notes. International Institute for Hydraulic and Environmental Engineering Delft Netherland.

World Bank 2014: Project Information Document concept stage.

Colophon

This Overview Paper is prepared by Eng. Dr. Maung Maung Htay, Technical Advisor, NEPS (National Engineering and Planning Services), information.neps@gmail.com.

This paper is reviewed and edited by David Mornout (MetaMeta) Reiner Veldman (MetaMeta) and Madiha Al Junaid (MetaMeta).

This Overview Paper builds on Overview Paper 9, Spate Irrigation in Myanmar available on www.floodbased.org.

The Flood-Based Livelihoods Network supports and promotes appropriate programmes and policies in spate irrigation, exchanges information on the improvement of livelihoods through a range of interventions, assists in educational development and supports in the implementation and start-up of projects in spate irrigation.

For more information and resources on Spate Irrigation and other Flood-Based Farming Systems visit www.floodbased.org or contact us through info@floodbased.org.

July 2021