APPLICATION OF THE RIVER ANALYSIS SYSTEM MODEL FOR THE PLANNING OF THE CASCADE WEIRS IN THE PING RIVER IN TAK PROVINCE

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ABSTRACT

During the Royal Irrigation Department (RID) had taken the Bhumibol Dam's construction at Sam Ngao District in Tak Province in Thailand, 2-pumping stations were first installed in order to supply water to their mitigated people who moved from the proposed reservoir area to the downstream of the dam. After the completion of the dam construction, the river water level in the Ping River downstream of the dam was tended to be lower than the riverbank and farmer never met inundate flow to their farmland. So, the RID constructed more 8-pumping stations to cope the commanded area of 6,200 hectares in Tak Province and completion in 1972. Recently, the amount of river flow to the Ping River and its tributary streams including the Wang River has been declining and causes to the recession of water level in the Ping River particular at downstream of the Bhumibol Dam. Most of pumping stations cannot be fully performing but followed the water flow released from the dam based on the power scheduling of the Electricity Generating Authority of Thailand (EGAT) whose operates the dam. Therefore, most of the pumping irrigation systems were never met the designed with fully supply yet since 1981. An alternative project to challenge the river stage problem in the Ping River particular at downstream of the Bhumibol Dam with the cascade weirs was proposed in order to maintain water level in the river in front of those pumping units during drought season. The River Analysis System (HEC-RAS) model from the Hydrologic Engineering Centre (HEC, USACE) was applied for the daily unsteady flow simulation of the behavior's water surface profiles in the Ping River downstream of the dam with the both cases of the worst case of flood in 2011 and worst case of drought in 2013. The comparison of water surface profiles in cases of prior and proposed 3-weirs project were modelled too.

The results show the benefit effect of 3-cascade weirs to maintain of water level during dry season for those 4-pumping units of RID and other agencies pump stations in Sam Ngao, and Ban Tak Districts in Tak Province with fully pumping based on the released flow from the EGAT within 5-6 hours per day during peak load of power consumption.

Keywords: HEC-RAS, cascade weir, pumping irrigation project, the Ping River.

INTRODUCTION

The Royal Irrigation Department (RID) had taken during the period construction of the Bhumibol Dam at Sam Ngao District in Tak Province in Thailand, 2-pumping stations were initially installed in order to supply water to their mitigated people who moved from the proposed reservoir area to the downstream of the dam at pump unit number 9 and 10 respectively. After the completion of the dam construction, the river water level in the Ping River downstream of the dam was tended to be lower than the riverbank and farmer never met inundate flow to their farmland. Therefore, RID built more 8-pumping stations completed in 1972 namely pump unit 2, 3, 4, 5, 1, 8, 6, and 7 from upstream to downstream of the Ping, respectively in order to cover overall commanded area of 10 pumping stations with 7,200 hectares in Tak Province. The location of 10-pumping units and their basic information show in table 1 and figure 1. Recently, the amount of river flow to the Ping River and its tributary streams including the Wang River has been declining and causes to the recession of water level in the Ping River particular at downstream of the Bhumibol Dam. Most of pumping stations cannot be fully performing but followed the water flow released from the dam based on the power scheduling of the Electricity Generating Authority of Thailand (EGAT) whose operates the dam. Therefore, most of the pumping irrigation systems were never met the designed with fully supply yet since 1981. All permanent pumping stations have to wait for the water level in the river rose above the level of the pump-skull particular in Sam Ngao and Ban Tak districts which mostly depends on the release flow from the Bhumibol dam based on the peak electric power consumption about 4-6 hours/day (Peak Load). The system previously designed of pumping systems with full time supply water to cope their cropping needs as supplementary rainwater which will be smaller pumping and canal systems. Therefore, the provincial irrigation office in Tak has tried to do rotational water supply in the irrigation systems using existing pumping systems plus more other temporary mobile-pump units to lift water from the river to irrigation canal in the period of released flow from the dam. Farmer’s activities also have been adapted water distribution to their farmlands in the same period of released flow too. However, those irrigation canal systems of the pumping units were not properly designed as for the rotation distribution supply system yet. Most of irrigated farmers complaint to RID that they are not convenient to lift water up by themselves and requested to RID to solve this problem i.e. release more dam released flow, construct more storage ponds, more pumping stations, including check dams or weirs in the river etc. The research of this issue was started to study as for the major aim of increasing pumping systems efficiency by using properly improvement methods i.e. rising of the water levels in the river in front of those pumping stations, returning of overall pumping efficiency with non-change of existing cropping calendar. Some of alternative proposed projects were compared and revealed that the most benefit direct for pumping units are to develop the cascade weirs in the Ping River just downstream of those pump stations who's met from critical river stages at pump unit no.9, 10, and 3 in Sam Ngao and Ban Tak districts downstream of the Bhumibol dam.

Table 1. Location of 10-pumping units and their basic information

Pump unit no.	District	Irr. Area, ha	Constructed year	Diameter-units	Irr. Canal length, km
1	Muang	1,200	1970	20"-2	26.183
2	Ban Tak	1,200	1970	24"-4	18.875
3	Ban Tak	1,360	1970	24"-3	33.33
4	Muang	880	1972	24"-1	21.08
5	Muang	432	1972	24"-1	14.82
6	Muang	352	1972	24"-1	9.993
7	Wang Chao	368	1971	24"-1	11.846
8	Muang	288	1971	24"-1	10.5
9	Sam Ngao	800	1962	24"-1	14.51
10	Sam Ngao	320	1962	20"-1	4.09
Total 10		7,200		20-24",1-4	165.227

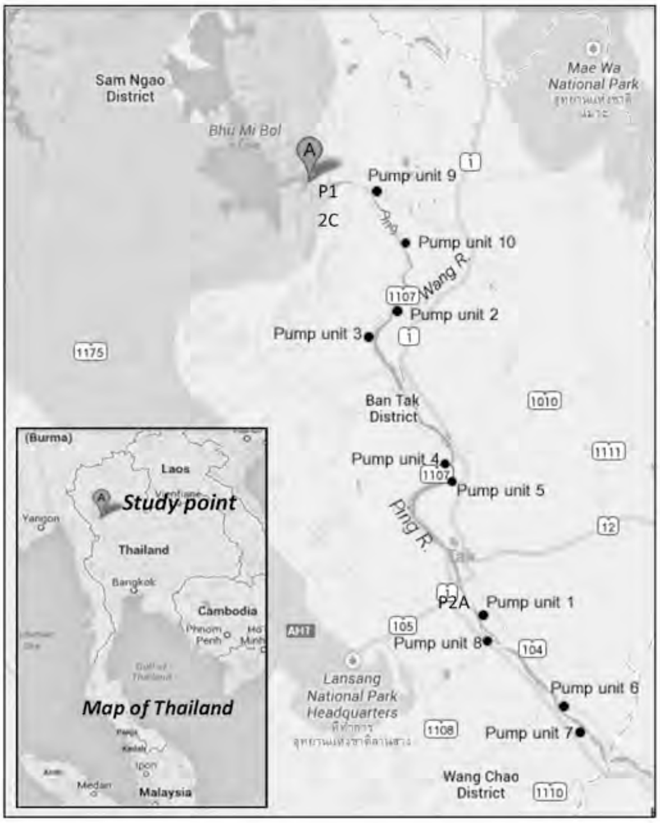

Figure 1 Map of the Bhumibol dam and location of pumping stations

MATERIAL AND METHOD

The study was divided in 3 parts. Firstly, the review of water demand basis by monthly for all kinds includes human consuming, industrial, agriculture: crop water requirement with most growing of paddy field, corn, and bean was studied. Secondly, the investigation of current water supply systems of 10-pumping units and their performances were monitored. Those relevant data such as topographic maps, satellite imageries, location of each pumping station, layout of delivery canals, irrigation structures, on-farm systems, drainage channels, existing land use types, cropping patterns & watering schedule calendars, and etc. were gathered. The climatological data; included rainfall, air temperature, air humidity, wind velocity, solar radiation, and evaporation were also collected with the aim for study crop evapotranspiration and consumption water use for all crops at farmland systems. Thirdly, the study covered all parts of hydrological systems for the lower part of Ping River Basin located the downstream of the Bhumibol Dam in the districts of Sam Ngao, Ban Tak, Muang and Wang Chao districts in Tak Province, respectively. Those were used to analyse of hydro-statistic, water balance, rainfall-runoff relationship, and water surface profiles in the Ping River from the downstream portion of the Lower Ping Dam downstream of the Bhumibol dam belong to EGAT at hydrological observation station: P12C (sta. 80.9; pump unit 9 at Sam Ngao district) via midstream at P2A (sta. 26.0; pump unit 1 at Muang district) till to the downstream end of Tak Province at Wang Chao district (sta. 0.0) with overall stream length of 80.9 kilometres (shown in figure 1). Due to insufficient rainfall and stage recording in ungauged catchments, the proportional by using known area-runoff relationship from neighbouring catchments were used to apply for this study. All secondary data included some river cross-sectional data, daily river stages, and rainfall amounts recorded were provided by the related agencies from the Royal Irrigation Department (RID), and Thai Meteorological Department (TMD). Moreover, the construction of contour-lines from existing digital elevation model (DEM 30 m.) and land-uses classification map were carried out by using sight interpretation existing Landsat satellite from the Geo-Informatics and Space Technology Development Agency (GISTDA) and aerial photo maps from the Land Development Department (LDD).

For the study of water surface profiles along the Ping River from downstream of the Bhumibol dam in Sam Ngao to end of Tak Province in Wang Chao districts both in drought period in 2013 and maximum flood level in 2011, the mathematical simulation model for river analysis system: HEC-RAS (USACE, 2010) was applied for the investigation of key hydraulic parameters of its river channel and used for the appropriated the height of proposed weirs to be lifted river water for those upstream pump units. The results from investigation show that there are some critical pumping units i.e. no.9, no.10, and no.3 with rarely get water from the river without released flow from the dam should be the first priority project development to be raised the river water level using proposed 3-weirs as cascade weir systems at downstream of those pump stations, respectively.

The assumptions of one dimensional (1-d) unsteady non-uniformed daily flow in both drought and flood seasons and studied in case of before and after proposed 3-weirs were applied to the main river. The briefly principle of HEC-RAS model for water surface profile studying is discussed as the following paragraph (figure 2).

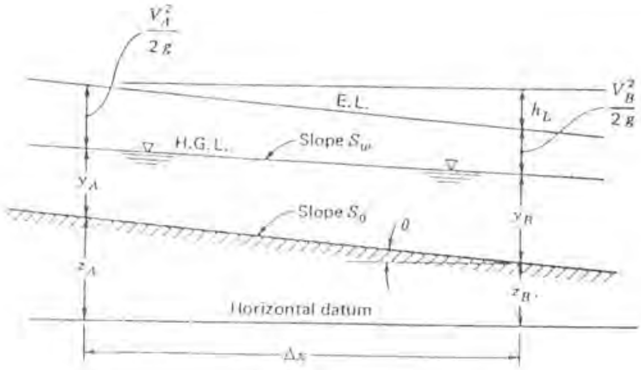

Figure 2 General concept of flow and water surface profile in an open channel

The energy equation (Chow et.al., 1988) between section A and B will be

$$z_A + y_A + \frac{V^2}{2g} = z_B + y_B + \frac{V^2}{2g} + h_L \qquad (1)$$

Where, z = the elevation of riverbed in m above mean sea level (MSL)

y = flow depths in m

V = average flow velocity in m/s

h_L = head losses between section A and B in m

The Manning equation (Chow et.al., 1988) as for discharge computation in open channel will be

$$Q = \frac{1}{n} A R^{2/3} S^{1/2} \qquad (2)$$

Where, Q = the discharge = AV in cu.m/s

A = cross sectional area of open channel in square m

n = average roughness coefficient (Manning) of the channel

S = average longitudinal slope of the channel = hL/L

R = average hydraulic radius = A/P in m

P = avearge wetted perimeter of the channel in m

The energy, and momentum equations (3) and (4) for the open channel (figure 3, 4) will be

$$(\partial A/\partial t)\,\Delta t \quad = -\,V_m(\partial A/\partial L) - A_m\,(\partial V/\partial L) \qquad (3)$$

Where, m = subscriptions for the mean values of V and A

L = length of the considered channel in m

t = incremental time to be calculated i.e. 1 days

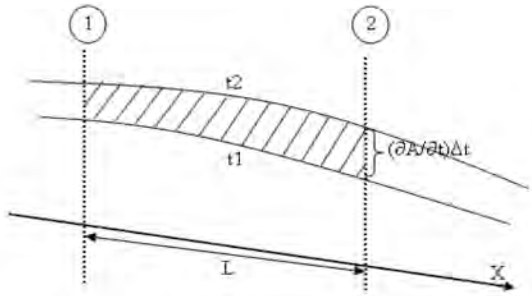

Figure 3 Flow energy concepts in an open channel

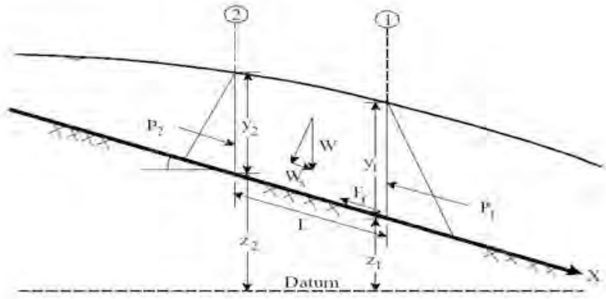

Figure 4 Momentum concepts of flow in an open channel

$$P_2 - P_2 + W_X - F_f = \rho AL\,[\partial V/\partial t + V\partial V/\partial t] \qquad (4)$$

Where, P = hydrostatic pressure forces at section 1 and 2

W_x = weight of water in direction x

F_f = friction force from section 1 to 2

r = density of water

The HEC-RAS (USACE, 2010) was applied as a model for computing water surface profiles at each cross-sectional profiles of the river which the rivers cross sectional profiles were done by field surveying.

The basically pump station, riverbank, riverbed, pump-skull level, flood water level (FSL or Max.WS) in 2011 data were shown in table 2, and figure 5.

Table 2 Riverbank, riverbed, skull, flood water levels at each pump (m. above MSL)

unit	sta. KM	riverbank level	riverbed level	skull level	FSL in 2011
P12C	80.92	134.21	130.17	-	133.95
Pump u 9*	76.58	135.85	125.41	128.68	130.26
Pump u 10*	72.33	133.20	123.19	127.35	129.06
Pump u 2	63.19	128.00	121.01	123.25	128.03
Pump u 3*	59.13	126.76	120.64	121.23	126.18
Pump u 4	41.68	117.48	112.50	112.60	115.80
Pump u 5	41.14	116.88	112.25	112.23	115.17
Pump u 1	21.90	107.00	100.18	102.04	107.18
Pump u 8	19.47	106.42	98.98	100.69	105.40
Pump u 6	8.82	100.24	94.21	96.13	99.98
Pump u 7	6.34	99.72	93.20	95.12	99.17
End	-	96.51	90.17	-	97.00

Note * location of proposed weirs.

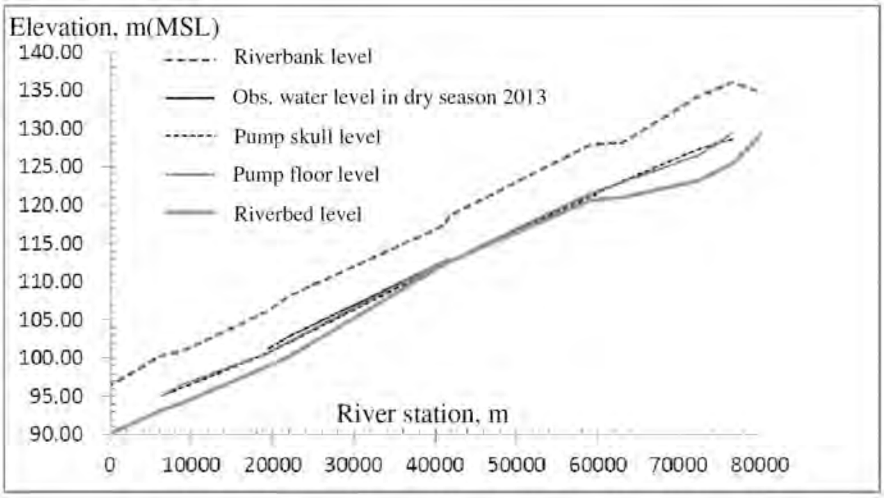

Figure 5 Profiles of the observation of Ping River and pumping levels data

From the basically data in table 2, pumping unit no. 9, 10, 2, and 3 are great effected by the released flow from the Bhumibol dam. The proposed 3 weirs as cascade weir systems at downstream of pumping unit no. 9, 10, and 3 at sta. 75.4, 70.5, and 59.1 KM will rise water level upstream of those weirs for pumping unit no. 9, 10, 2, and 3, respectively. Moreover, the benefit will also effect to those small scales and farm's pumping stations upstream of proposed cascade weirs in figure 6.

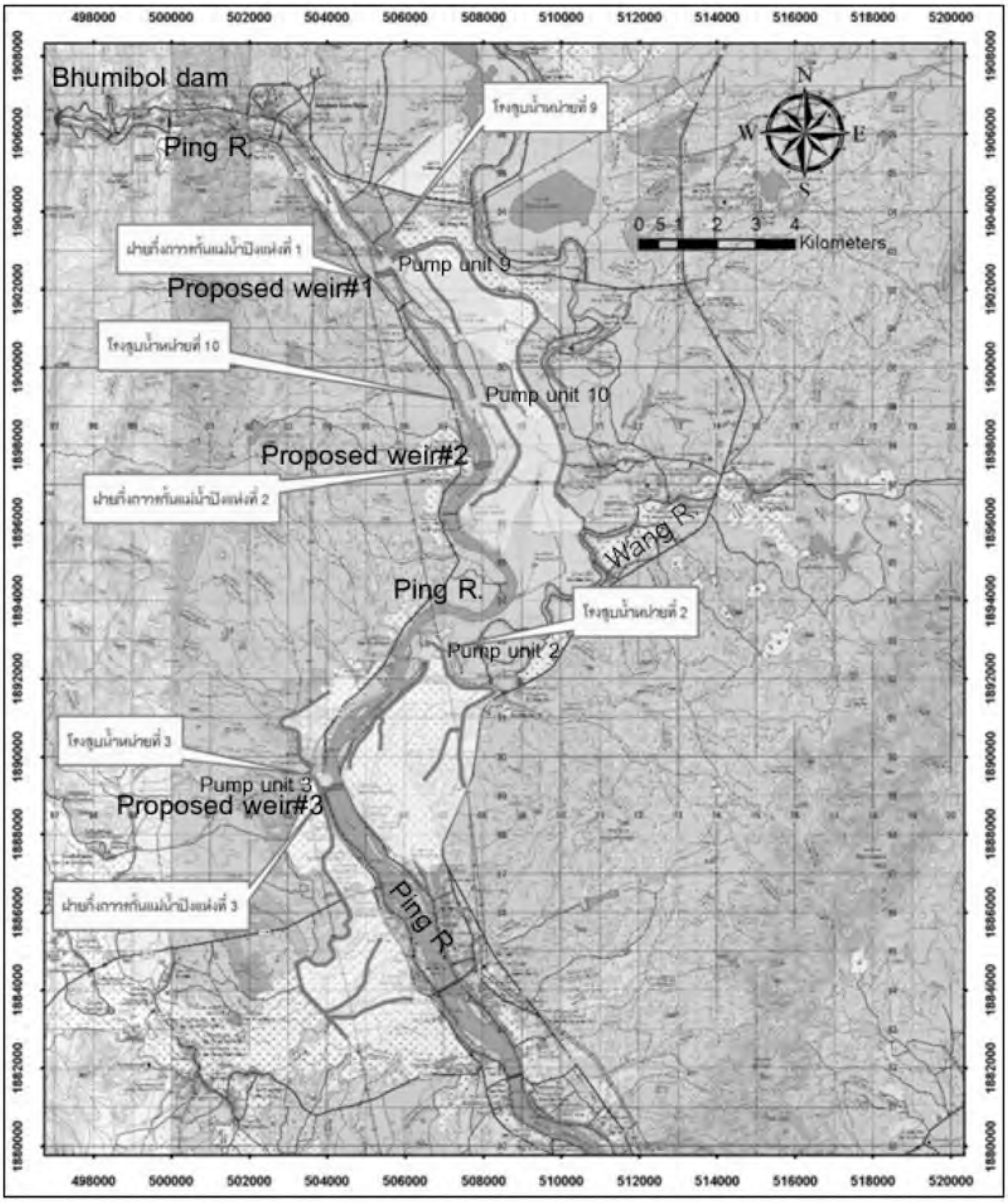

Figure 6 Location of pumping unit and proposed 3-weirs for pump unit #9, 10, 3

The River Analysis System (HEC-RAS) model from the Hydrologic Engineering Centre (HEC, USACE) was applied for the daily unsteady flow simulation of the behavior's water surface profiles in the Ping River downstream of the dam with the both cases of the worst case of flood from August 7 to November 29, 2011 and worst case of drought in October 13-18, 2013. The next paragraph showed the results of the analyse of water profiles along the Ping River at each station using 1-demensional unsteady flow river analysis system model (HEC-RAS) during the period of drought with lack of river flow and peak flood level in 2011. The surveying results of cross sectional profiles at each step length of 2-5 kilometres from P12C via P2A (sta. 26.0 at Muang) and endpoint at P18 (at Wang Chao) had been investigated with total length of 80.9 km. Examples of cross sectional profile were shown in figure 7. The proposed of weir heights 3-4 m. were used in the model according to each pump skull levels. The boundary conditions (BC) in HEC-RAS applied daily flow hydrograph with released from the Bhumibol dam as upstream BC and the normal depth with average friction slope of 0.0008 as downstream BC. Whiles as the uniform lateral inflows in to the Ping River upstream of each weir were estimated using catchment's proportional method from gaged or hydrological observation stations for unsteady flow in HEC-RAS model.

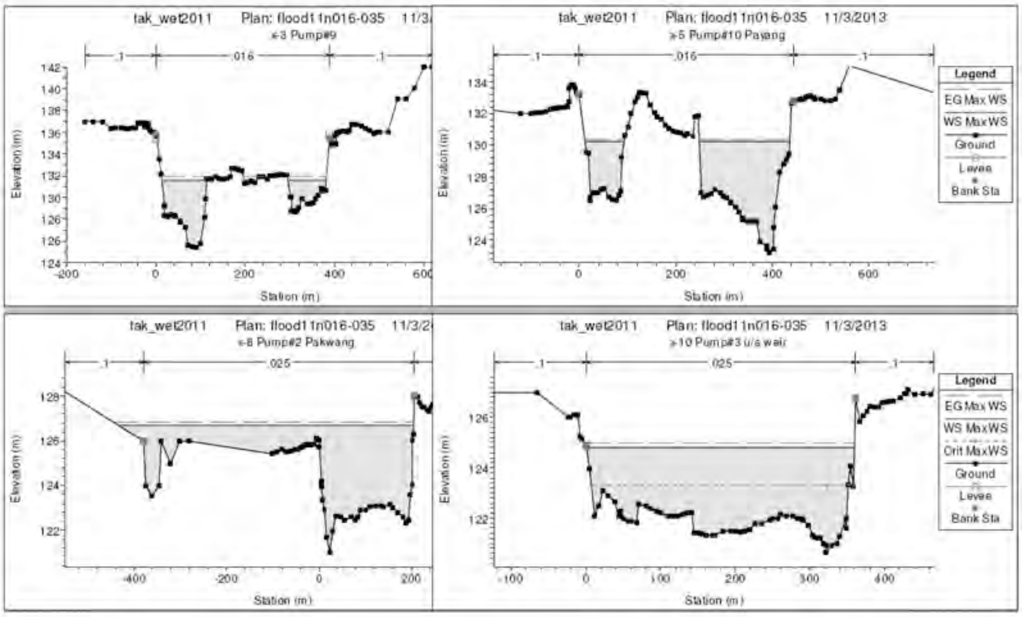

Figure 7 Cross sectional profiles & river water level in the Ping River at each station.

RESULTS AND DISCUSSIONS

From the terrain level of the area along the Ping River in Tak province measured from the down-stream of the Lower Ping dam (downstream of Bhumibol dam) at hydrological station P12C (sta. 80.9) down to the farthest Tak at Wang Chao at the hydrological station P18A (sta. 0.0) found that the Ping River, with a length of about 80.915 km with the riverbed slope of 0.0031 to 0.0083 in the downstream regions (Wang Chao - Muang) to the upstream part (Muang – Sam Ngao) with the bottom level at the Lower Ping dam of +130 and the downstream end at Wang Chao of +87 m (above MSL), with the average slope of 0.00051, and the average roughness coefficient (n-Manning) of 0.026, respectively. The model was calibrated and tested using observed daily discharges as upstream boundary conditions at P12C and river water levels (Obs. RWL or WS) data from October 12 to November 13, 2011 and compare to the simulated river water level results (Sim. RWL or WS) at P12C and P2A, respectively.

The results of Sim. RWL and Obs. RWL at P2A (sta. 26.0) were fitted by linear regression analysis with R2 equal to 0.8175 (figure 8).

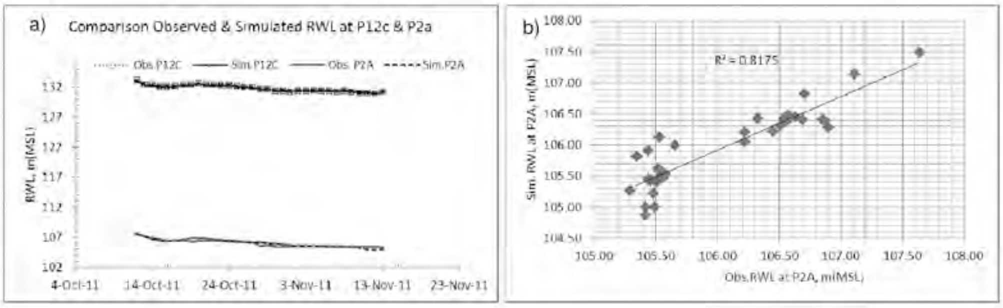

Figure 8 a) Comparison of daily Sim. & Obs. RWL at P12C & P2A,

b) Regression analysis result of Sim. & Obs. RWL at P2A between Oct.12 to Nov. 13, respectively.

The schematic plan of Ping's river reach and location of cross-sectional profiles were shown in figure 9. Those results of daily WS with proposed 3-cascade weirs at sta. 75.4, sta. 70.5, and sta. 59.0 during flood (WS in 2011) and drought (WS at October 18, 2013) showed in figure 10 to figure 11, respectively. The verification results of WS were verified by using observed water depth from gaging stations and field surveyed with very fit described in table 2, figure 5, and figure 11, respectively.

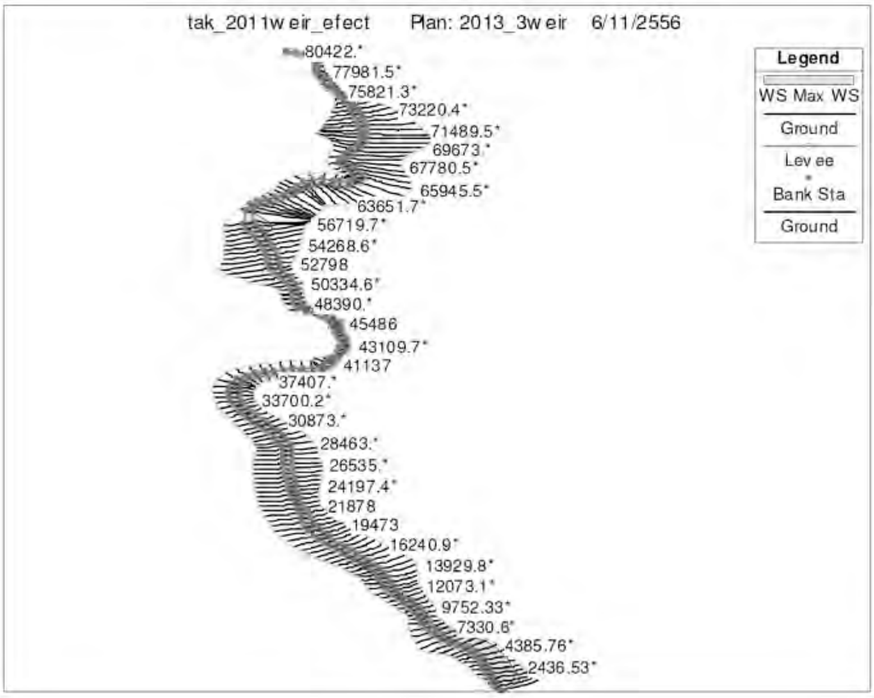

Figure 9 The plan of Ping's river reach and cross-sectional profiles in HEC-RAS

The result of Max. WS with proposed 3-cascade weirs during flood (WS in 2011) in figure 10 was not affected by raising the river water level with only 0.1-0.2 m above existing WS (without proposed 3-weirs) at some locations.

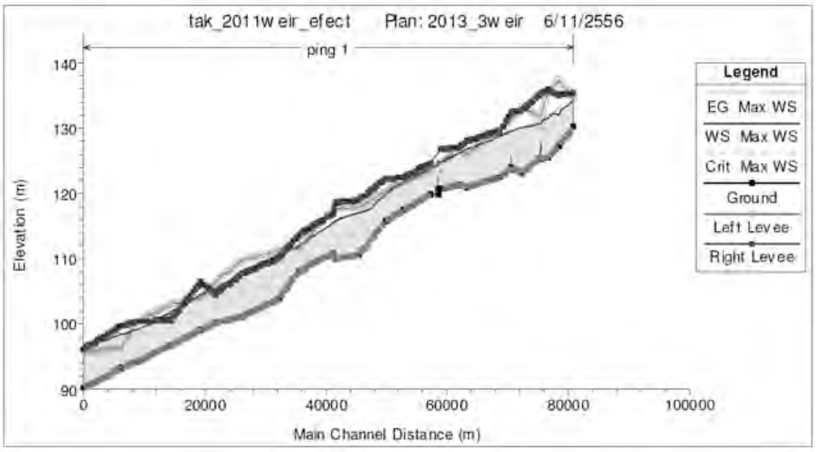

Figure 10 Simulated Max. WS in the Ping R. in 2011 with proposed 3-weirs

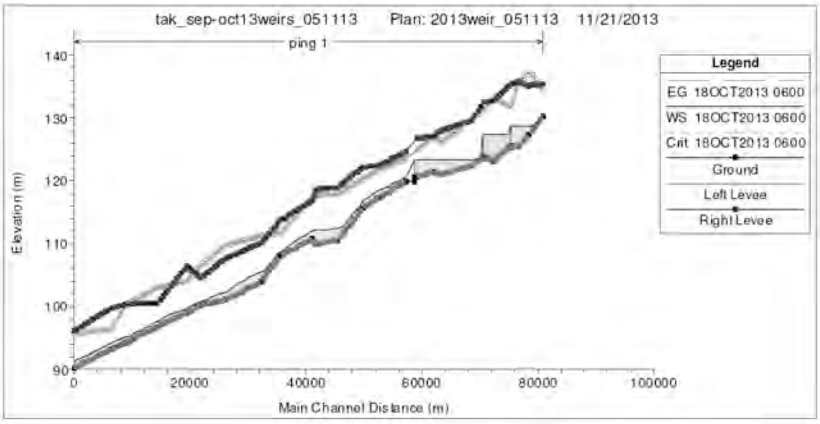

Figure 11 Sim. WS in the Ping R. on October 18, 2013 with proposed 3-weirs

The result (figure 11) showed the benefit effect of 3-cascade weirs to maintain of water level during dry season even though no released flow from the dam during a day for those 4-pumping units of RID and other agencies pump stations in Sam Ngao, and Ban Tak Districts in Tak Province with fully pumping based on the released flow from the EGAT within 5-6 hours per day during peak load of power consumption.

CONCLUSIONS

The study of proposed 3-cascade weirs based on hydraulic phenomenon applied mathematical simulation model for river analysis system (HEC-RAS) which can be further construction drawing and project development for the beneficial maintain the river water depth in front of each pumping units during drought period for increasing pump performance efficiency and their irrigation systems.

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