

UPAYA OPTIMASI OPERASI SISTEM TATA AIR DAERAH IRIGASI RAWA DADAHUP DI KALIMANTAN TENGAH

EFFORTS TO OPTIMIZE THE OPERATION OF THE DADAHUP LOWLAND IRRIGATION AREA IN CENTRAL KALIMANTAN

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ABSTRACT

Dadahup lowland irrigation area is one of the areas developed as a food estate. Land cover change to shrubs is caused by channels with buildings that are not functioning optimally, so it is often hit by floods and droughts. One of the efforts to improve the function of channels and buildings is to control the minimum water level of 60 cm in the dry season and the maximum water level of 10 cm in the rainy season. This study aims to determine the optimal operations and maintenance through adjusting the elevation of the gate opening to achieve the quantity and quality for the development of water management systems in lowland irrigation. The research method was carried out with hydraulic simulation based on the tides of the Barito River Mouth, discharge, rainfall, and pH obtained from telemetry monitoring system with openings of all sluice gates in primary channels and secondary channels. The results showed that operation and maintenance optimization can be done by setting primary and secondary sluice gates that are opened at a water level elevation above + 0.5 m in the dry season as supply and water level elevation + 1.1 m in the rainy season as drainage. Primary and secondary sluice gates are closed at water levels below + 0.5 m to maintain water levels and water quality.

Keywords optimization, lowland, Dadahup Lowland Irrigation Area, HEC-RAS, hydraulic

ABSTRAK

Daerah irigasi rawa Dadahup merupakan salah satu daerah yang dikembangkan sebagai lumbung pangan. Perubahan tutupan lahan menjadi semak belukar disebabkan oleh saluran dengan bangunan yang tidak berfungsi secara optimal sehingga sering dilanda banjir dan kekeringan. Salah satu upaya untuk meningkatkan fungsi saluran dan bangunan adalah dengan mengendalikan tinggi muka air minimum 60 cm pada musim kemarau dan tinggi muka air maksimum 10 cm pada musim hujan. Penelitian ini bertujuan untuk mengetahui pola operasi dan pemeliharaan yang optimum melalui pengaturan pintu dalam mencapai kuantitas dan kualitas air yang sesuai untuk pengembangan sistem tata air di lahan irigasi rawa. Metode penelitian dilakukan dengan simulasi hidraulika berdasarkan pasang surut muara Sungai Barito, debit, curah hujan, dan pH yang diperoleh dari sistem monitoring telemetry dengan bukaan setiap pintu air pada saluran primer serta saluran sekunder. Hasil penelitian menunjukkan bahwa optimasi operasi dan pemeliharaan dapat dilakukan dengan pengaturan pintu air primer dan sekunder yang dibuka pada elevasi muka air di atas + 0,5 m pada musim kemarau sebagai supply dan elevasi muka air + 1,1 m pada musim penghujan sebagai drainase. Pintu air primer dan sekunder ditutup pada elevasi muka air di bawah + 0,5 m untuk menjaga tinggi muka air dan kualitas air.

Kata Kunci: optimasi, rawa, Daerah Irigasi Rawa Dadahup, HEC-RAS, hidrolika

INTRODUCTION

The Government's program known as the Food Estate in Central Kalimantan Province is divided into four blocks consisting of blocks A, B, C, and D and is one of the priorities for irrigated land development with the aim of realizing national food security, especially in Indonesia (Syakirotin et al., 2022). The development of irrigated land by reconstructing and developing lowland irrigation networks in the working areas of blocks A, B, C, and D has a total target of 165 thousand hectares of lowland irrigation service area spread across Kapuas and Pungur Regencies in Central Kalimantan Province (Yestati and Noor, 2021). The Dadahup Lowland Irrigation Area is one of the block A working areas that has the potential to be developed. This region, which covers around 25,000 hectares, is part of the Barito, Kapuas Murung, and Mengkatip River Watersheds, which are quite large and have intense rainfall (Virama Karya, 2020).

The Dadahup Lowland Irrigation Area has experienced frequent natural disasters such as floods, droughts, and forest fires. These events have caused the agricultural land in the area to change or transform into plantations, shrubs, and settlements (Arif et al., 2021). This condition is exacerbated by the non-optimal function of irrigation networks and causes agricultural land to become unproductive agricultural land. The impact of disasters and non-optimal management results in agricultural land not being reached and turning into unproductive land.

The existing water management system in Dadahup Lowland Irrigation Area is divided into several macro and micro-tertiary plots with a main channel network consisting of primary, secondary, and collector channels whose flow direction is parallel to the flow direction of the river network (Magdalena et al., 2022). The water quality in the Dadahup tertiary plot is quite low, as it is dominated by shallow pyrite depths that contain acid (Das, 2015). One of the initiatives carried out by the UGM Research Team is the installation of a telemetry monitoring tool that aims to observe changes in water dynamics, both in quantity and quality (Arif et al., 2022).

Efforts to regulate the quality and quantity of water in lowland irrigation areas must be supported by management of operation and maintenance patterns of irrigation networks (Lestari et al., 2019). The implementation of operation and maintenance of floodgates on lowland irrigation networks generally aims to maintain a water level of 50-60 cm

below ground level in the dry season and maintain a water level above 10 cm from the elevation of water needs in the rainy season (BPSDM Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2022). Due to the complex hydrodynamics characteristic, internet-based telemetry system will provide substantial role to increase the effectiveness of operation and maintenance effort. The development of this system is a common approach in Irrigation Modernization which includes 3 main elements, namely sensors, internet connections, and data centre (Muhaemin, 2018).

To support the efforts, this study aims to determine the optimal operations and maintenance through adjusting the elevation of the gate opening to achieve the quantity and quality for the development of water management systems in lowland irrigation area.

METHODOLOGY

Study Location

The study site is located in Dadahup Sub-district, Kapuas Regency, Central Kalimantan Province with coordinates 2° 40.963'S and 114° 41.099'E.

The research location is in the Dadahup Lowland Irrigation Area, which is flowed by the Barito River network consisting of 17 microblocks with 18 gate buildings in the primary and secondary channels shown in Figure 1.

The main source of water for Dadahup Lowland Irrigation Area is rainfall which falls into hydro-topography categories C and D (Wignyesukarto, 2000) by applying a polder system in water management equipped with pumping stations, culverts, and sluice gates (Noor et al., 2017).

The tidal movement in the Dadahup Lowland Irrigation Area, which originates from the Barito River, has an average tidal height of about 1.6 m (< 2 m). The tidal amplitude in Dadahup Lowland Irrigation Area is classified as micro tidal (Arisanty, 2013). Climatic conditions in the Dadahup Lowland Irrigation Area are included in climate type A, which is characterized by a higher number of wet months than dry months, and the pattern of rainfall distribution is almost evenly distributed, where wet conditions occur from November to April and dry conditions occur from May to October (Kurdi et al., 2020). The influence of tidal propagation from the Barito River with high salinity concentrations can reach distances up to 158 km upstream (Suriadikarta, 2012).

Data

This study used primary data, namely tidal observations with the Tidal Application at the Barito River Estuary, observations of water levels in the intake channel of the Dadahup Lowland Irrigation Area, observations of water levels at the main intake and secondary intake using measuring scales (points L and Q as in Figure 1), maximum daily rainfall and water quality in the channel using a telemetry monitoring system, and in the field using manual tools (Putra et al., 2022). Secondary data used in this study includes channel geometry profiles, irrigation network maps, and dimensions and elevations of division gate structures. This research was conducted through hydraulic simulation of water level dynamics using HEC-RAS software based on boundary condition data and cross-sectional geometry profiles of the irrigation network and the Barito River (Iswardoyo and Satria, 2023). The boundary conditions used consist of downstream water level hydrographs and upstream flow hydrographs (Mardani et al., 2020).

Method

The simulation of macro and micro water systems. This software was developed by the United States Army Corps of Engineers. The model is used at a professional level, which allows us to perform

one-dimensional steady flow and unsteady flow simulations. It is also used to design and develop one-dimensional full network hydraulics calculations for artificial and natural channels. The first stage was the hydraulic simulation of the macro water system using tidal data in the downstream and discharge data in the upstream of the Barito River (Salmani et al., 2013). The simulation results were calibrated with water level measurements in the main primary channels L, S, and S2 that are directly connected to the Barito River. The calibration test was carried out by changing the manning roughness coefficient factor inputted to the river geometry in HEC-RAS to match the observations in the field and become the basis for developing water system simulations. The second stage is a micro water system simulation with the development of a macro water system equipped with input variations in the height of the gate opening in the primary and secondary channels.

The input of variations in gate opening height was simulated to achieve a water level of <0.6 m in the secondary channel in the dry season and <0.1 m in the field in the rainy season. The selected gate opening height becomes the basis for operation and maintenance optimization. The scope of the research activities is shown in Figure 2.

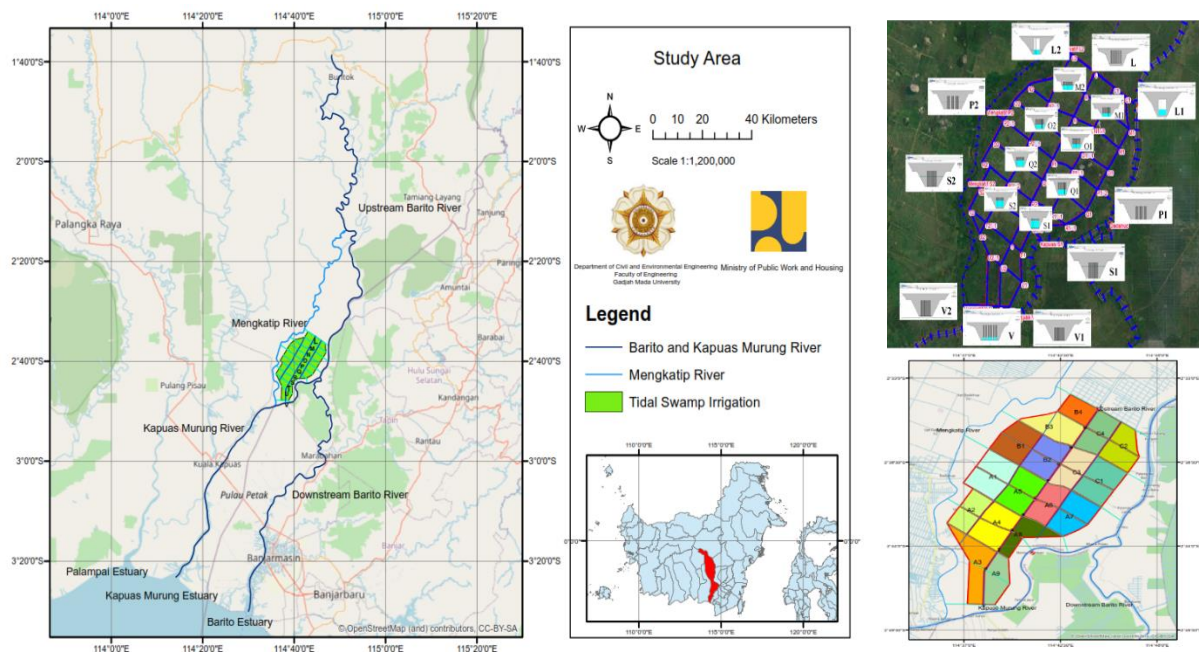


Figure 1 Study area

RESULTS AND DISCUSSION

The research discussion consists of several parts that analyze the results of the Barito River network simulation, calibration of simulation results with measurements, and optimization of operation and maintenance of irrigation networks based on macro and micro gate opening operation.

Simulation of Barito River Network Water Level Dynamics

The tides used for the hydraulic simulation of the water level were obtained from the Tides

Application on March 18, 2022 to March 31, 2022 for 15 days illustrating the highest tide elevation (spring tide) and the lowest tide elevation (neap tide) displayed in Figure 3.

The selection of the time span aims to be used as a calibration with the results of water level observations in the upper Barito River which is connected to the primary channel using measuring signs displayed in Figure 4. The flow discharge used in the upstream is the result of analysis with the NRECA Method within a period of 10 years of observations displayed in Table 1.

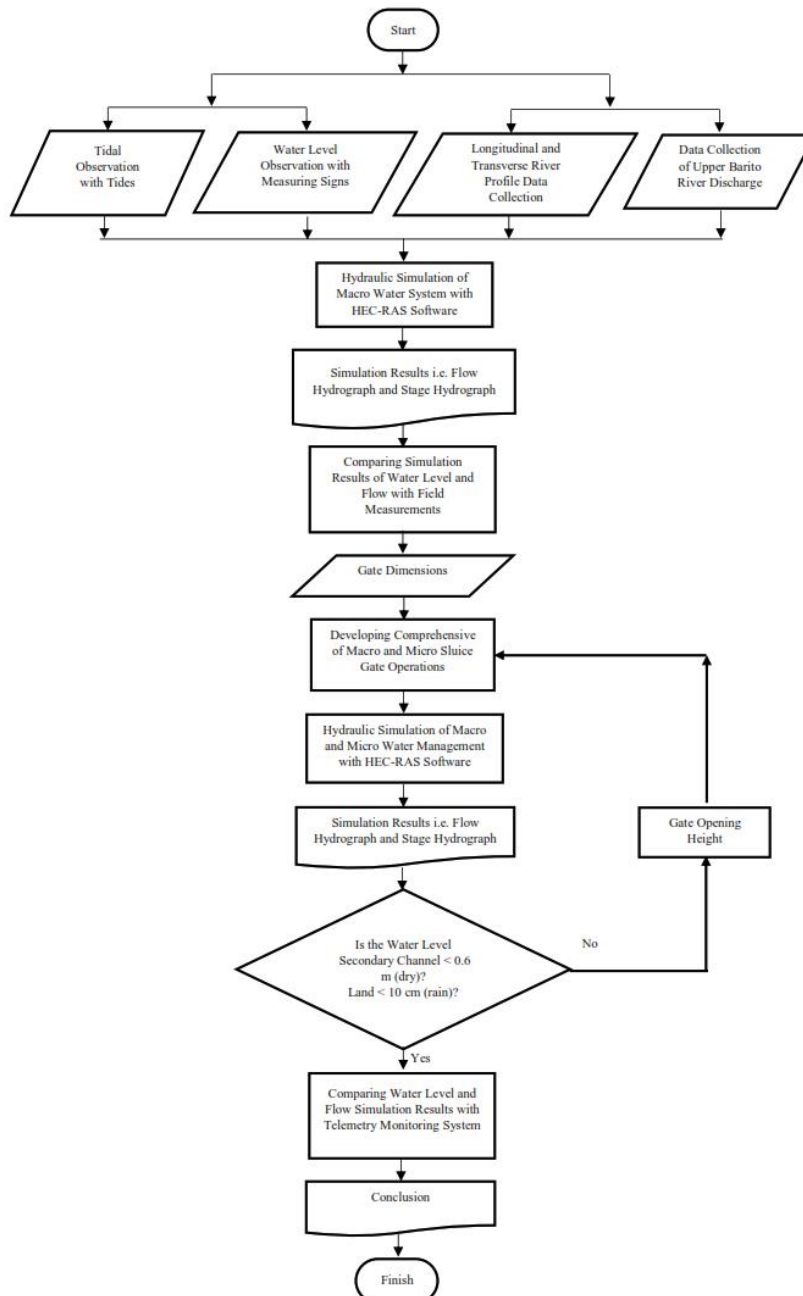


Figure 2 Research flow chart

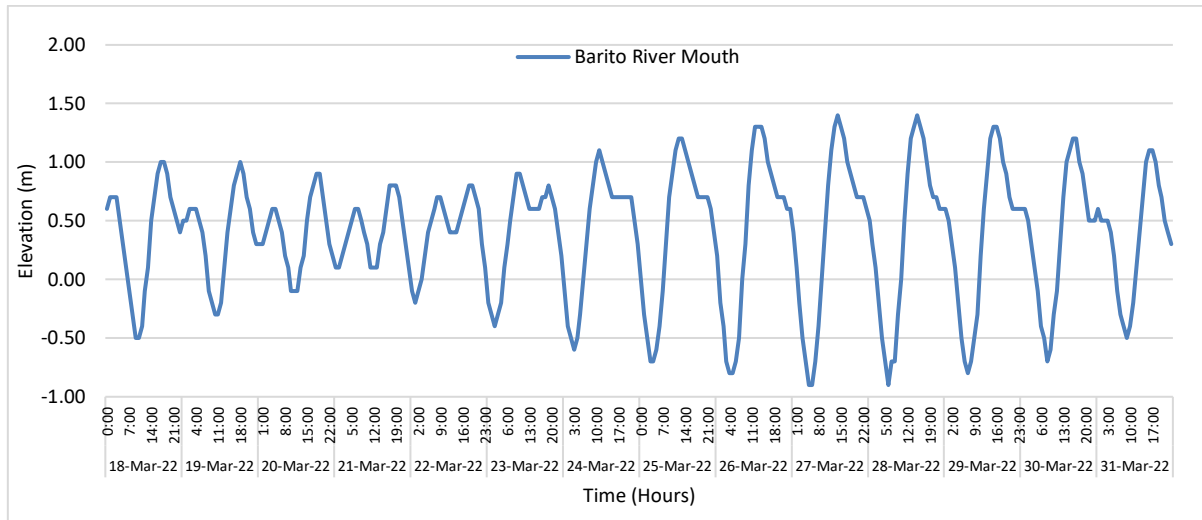


Figure 3 Tidal elevation of Barito river mouth with tides

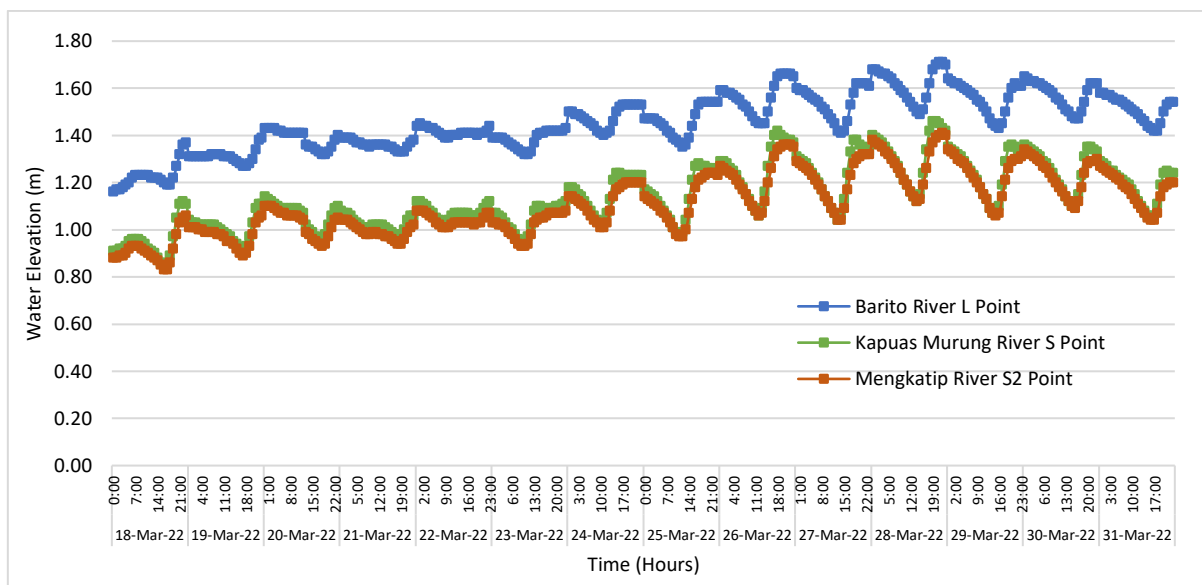


Figure 4 Measurement results of water level elevation at intake channel Dadahup

Table 1 Upstream Discharge Barito River

Tahun	Upstream Discharge (m ³ /s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	10.1	384.2	530.8	678.8	402.5	142	68.7	34.3	17.8	235.5	54.7	299.9
1998	286.6	90.7	73.1	1121.1	1422.9	1207	583.6	487.6	343.3	1520.9	603.1	1339.5
1999	740.5	1952.1	2567.3	1747.9	1886	1492.5	1115	946.8	457.9	467.5	173.8	753.6
2000	1560.3	1462.9	693.2	1393.5	1955.1	1195.4	492.9	221.8	876.6	4106.4	2169.6	2634.8
2001	1931.1	1175.1	1902.3	2321.6	1206.9	681.7	273	136.5	127.8	1516	887.9	961.6
2002	1379.6	1385.2	2350	1585.3	770.3	312.2	156.1	308.3	88.4	44.2	22.1	772.4
2003	818	829.3	854.9	1107	365.5	166.7	83.3	41.7	100.9	328.3	590.5	953.9
2004	885.9	1019.8	1167	1359.8	703.3	261.2	196.2	79.4	39.7	19.8	689.5	1727.2
2005	1066.5	826.3	1249.2	1623.2	1053.3	1021.8	319.9	703.5	452.1	1432.6	1858.8	1231.1
2006	1342.5	1772.4	1517.2	2109.1	1686.1	983.8	361.8	180.9	90.5	45.2	0	1199.8
Average	1002.1	1089.8	1290.5	1504.7	1145.2	746.4	365	314.1	259.5	971.7	705	1187.4

The tidal water level in the Barito River Mouth is included in the mixed semi-diurnal tidal type, where tidal events occur twice a day with different water level fluctuations (Runniawan et al., 2010). The tidal component of the Barito River Mouth can be known by using the Admiralty Method to calculate the category of water level elevation influenced by the moon and the sun (Ichsari et al., 2020). The results of the tidal component of the Barito River Mouth with tidal elevation categories are shown in Tables 2 and 3.

Table 2 Tidal Elevation Category of The Barito River Mouth in March

Category	Elevation (m)
Highest High Water Spring (HHWS)	1.3
High Water Spring (HWS)	1
Mean Sea Level (MSL)	0.4
Low Water Spring (LWS)	-0.5
Lowest Low Water Spring (LLWS)	-1

Table 3 Tidal Component of the Barito River Mouth in March

Component	S0	M2	S2	N2	K1	O1	M4	MS4	K2	P1
Amplitudo (cm)	1.67	0.29	0.03	0.09	0.70	0.33	0.00	0.00	0.01	0.23
g°		14.70	48.31	105.72	335.65	179.59	123.52	310.49	48.31	335.65

Water level measurements at the intake point of the Dadahup Lowland Irrigation channel were carried out at several points representing the river network, namely point L of the Barito River, point S of the Kapuas Murung River, and point S2 of the Mengkatip River. The measurement results show that the water level is strongly influenced by tides and upstream discharge. The water level at point S of the Kapuas Murung River is + 0.9 m to +1.3 m, the water level at the Mengkatip River is + 0.8 m to + 1.2 m and the water level at point L of the Barito River is + 1.2 m to + 1.6 m. The calculation of the upstream Barito River flow discharge is obtained from the calculation of the monthly mainstay discharge using the NRECA Method.

Data collection was carried out for 10 years in one month when the maximum monthly average discharge was in April amounting to 1504.7 m³/s and the minimum discharge was in September amounting to 259.5 m³/s. The condition of the amount of discharge can determine the condition of the wet month in May - April, while the dry month is in June - November. Simulation of the dynamics of the Barito River network water level based on boundary condition data, river geometry profile and Dadahup irrigation network with HEC-RAS Software and simulation results of the dynamics of the water level at the Dadahup channel intake point are shown in Figures 5 and 6.

Calibration of Water Level Dynamics Simulation Results

Calibration of water level dynamics simulation results is carried out between hydraulic simulation results with HEC-RAS and water level measurements at the review site (Pasquale et al., 2014). Water level dynamics that are influenced by the long geometry profile and cross section of the river network need to be matched with

measurements. One of the parameters that affects the simulation of water level dynamics is the channel roughness coefficient, or n_{manning} (Adane and Abate, 2022). The flow propagation is influenced by the value of the roughness coefficient manning is a major factor in changes in water level dynamics influenced by tides in the river mouth with discharge upstream (Jiang et al., 2021). The level of calibration accuracy can be calculated by the RMSE method between simulation results and measurements, where the RMSE value close to 0 is selected and qualified in simulation development (Ardianto et al., 2022; Yogafanny and Legono, 2022). The calibration graphs of the simulation results of water level dynamics with variations in the value of the manning roughness coefficient and the calculation results with RMSE are shown in Figures 7 and 8.

The results of the analysis with RMSE based on the variation value of the manning roughness coefficient show that the manning value of 0.04 produces an RMSE of 0.002 which almost meets the requirement of a value of 0. The manning roughness coefficient value of 0.04 is the selected value for further simulation development in the macro and micro water management network system with irrigation buildings (Rahajeng et al., 2021).

Hydraulic Simulation of Operation and Maintenance on Water Quantity

Hydraulic simulation of operation and maintenance of irrigation networks is carried out using HEC-RAS Software based on the gate opening plan with water level elevation. The gate opening plan operation consists of 10 macro water gate buildings with gate dimensions of $b = 2.5$ m and $h = 3$ m and 5 micro water gate buildings with dimensions of $b = 2$ m and $h = 2.5$ m.

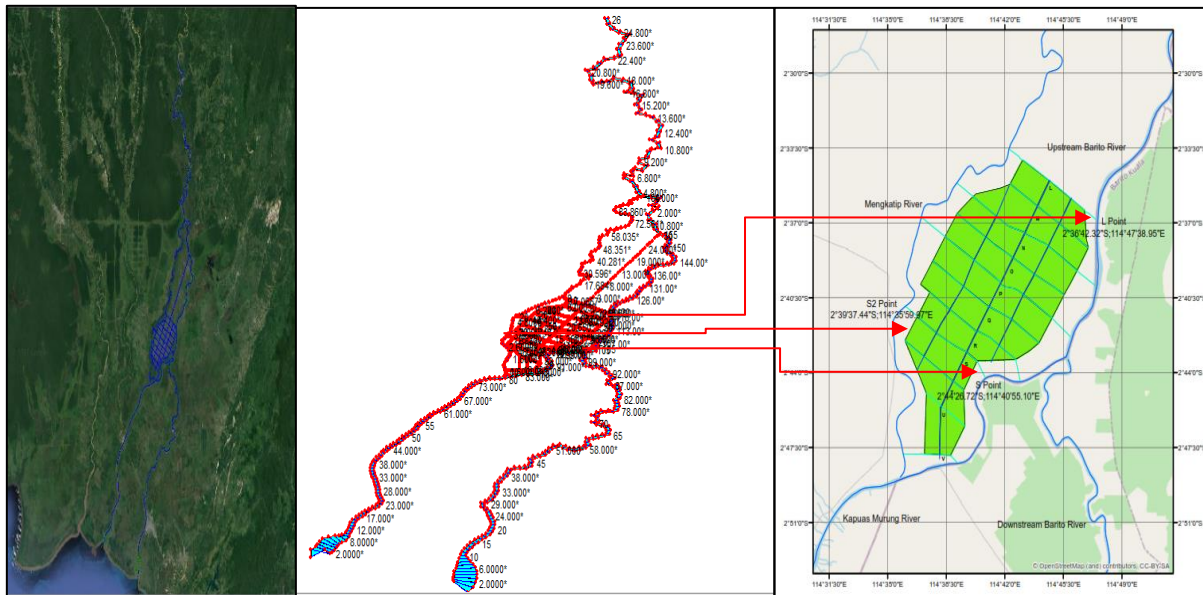


Figure 5 Boundary condition data simulation of water level dynamics of Barito river network Dadahup with HECRAS software

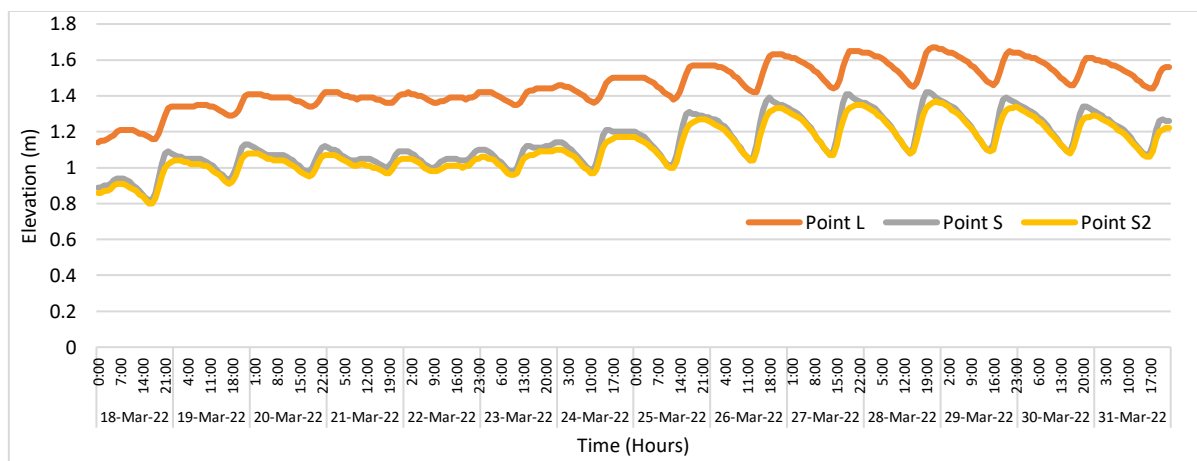


Figure 6 Water level elevation simulation results of Barito river network water level dynamics Dadahup with HECRAS software

The type of gate used is a sluice gate made of steel with manual operation using a gate opening steering wheel. The water level used in the hydraulic simulation is divided into two conditions, namely the rainy and dry seasons. The tides that serve as boundary conditions in the downstream part of the Barito River Mouth are obtained with Tides that are corrected or calibrated with telemetry monitoring system located in the main primary channel of Dadahup Lowland Irrigation Area. The time period used as the boundary condition is divided into two seasons, namely the rainy season in September and the dry season in August, shown in Figures 9 and 10.

The tidal data showed that the average tidal elevation in September was at elevation + 0.7 m

while in August it was at elevation + 0.5 m. The planned gate opening operations to achieve optimal conditions are described in Table 8. The gate opening operations described in Table 8 were input as reference data for hydraulic simulation with HEC-RAS with tidal and discharge data.

The input data of the gate opening plan is set at gate openings with a range of opening times per hour according to the tidal water level elevation data. The simulation results of the operation and maintenance optimization water level in the secondary channel Q Block A5 Dadahup Lowland Irrigation Area during the dry and rainy seasons are shown in Figures 11 and 12.

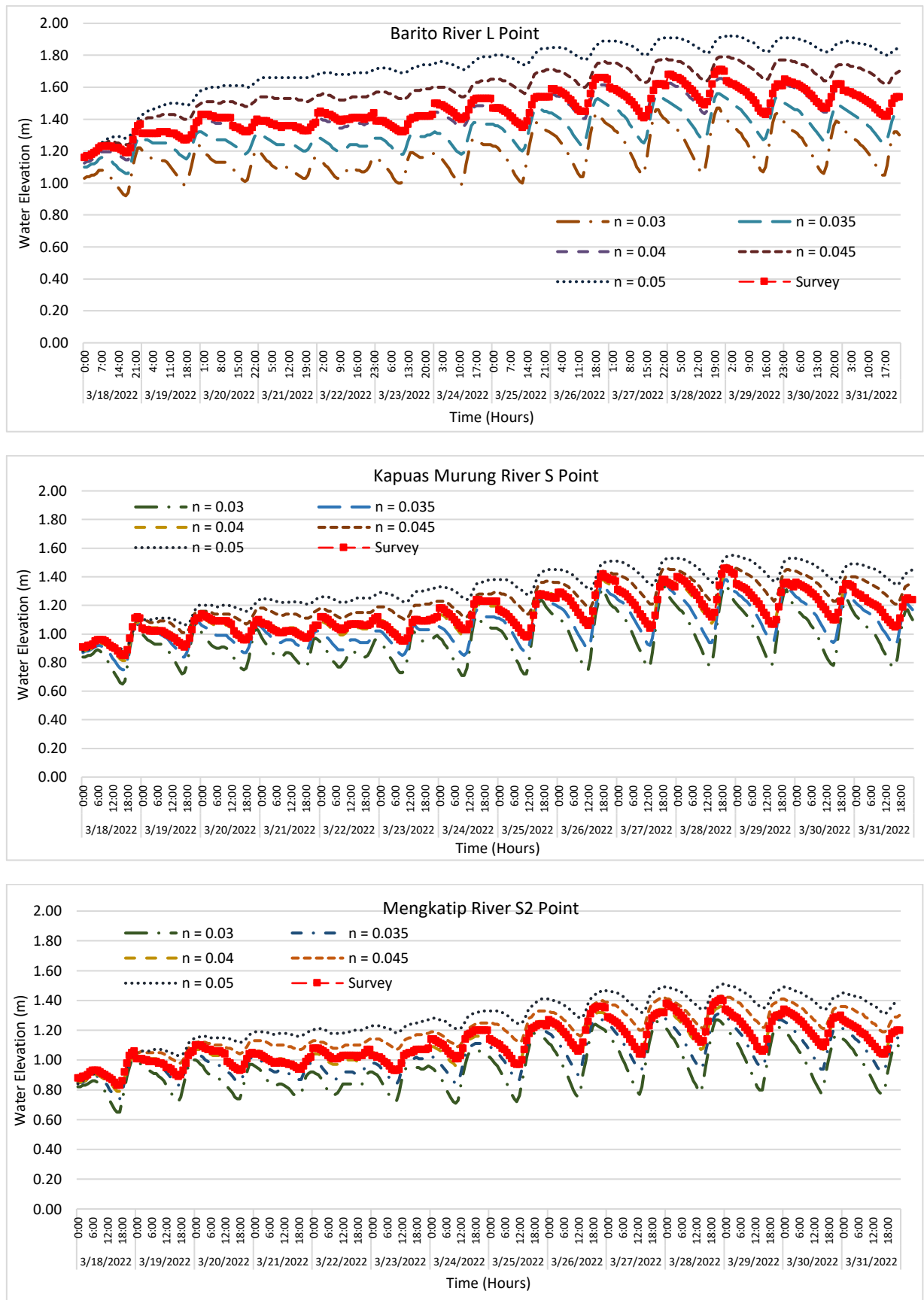


Figure 7 Calibration graph of water level elevation with variation of n_{manning}

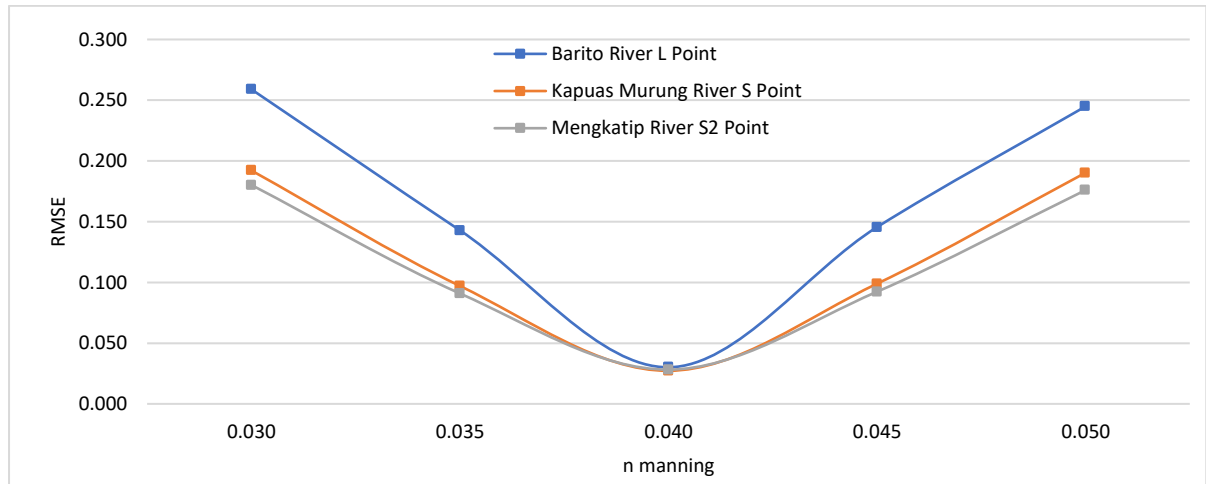


Figure 8 Graph of RMSE value based on variation of coefficient value

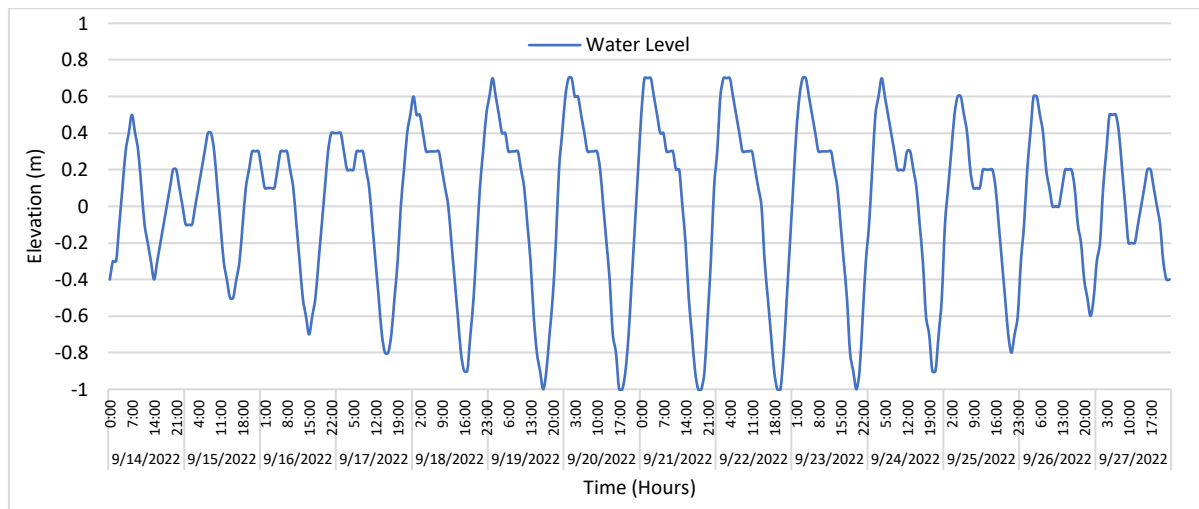


Figure 9 Barito river mouth tides in rainy season

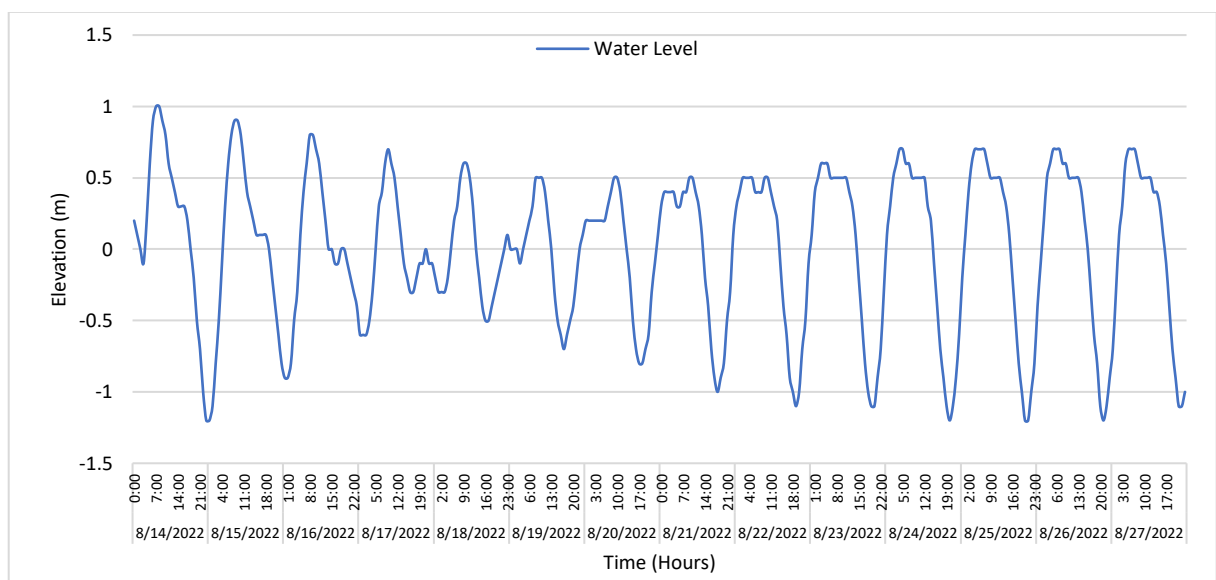


Figure 10 Barito river mouth tides in dry season

Table 8 Operation and Maintenance Optimization of Dadahup Lowland Irrigation Area

Season	Operation	Explanation
Dry	Macro Water Management System	1 The Main Primary Channel (SPU) functions as a drainage channel controlled by the Gate L.
		2 Additional Primary Channel (SPP) functions as a supply channel controlled by Gates L1 and L2.
		3 The Main Primary Channel (SPU) functions as a drainage channel controlled by Gate V with a gate opening of 0.8 m from the bottom to maintain the groundwater level.
		4 Secondary channels associated with the Barito, Mengkatip, and Kapuas Murung Rivers function as drainage channels controlled by Gates P1, P2, S1, S2, V1, and V2 to maintain water levels.
	Micro Water Management System	5 Secondary Gates M, O, Q, and S are opened at water levels above + 0.5 m and closed at water levels below + 0.5 m.
Rain	Macro Water Management System	1 The Main Primary Channel (SPU) functions as a drainage channel controlled by the Gate L.
		2 Additional Primary Channel (SPP) functions as a drainage channel controlled by Gates L1 and L2.
		3 The Main Primary Channel (SPU) functions as a drainage channel controlled by Gate V with a gate opening of 0.8 m from the bottom to maintain the groundwater level.
		4 Secondary channels associated with the Barito, Mengkatip, and Kapuas Murung Rivers function as drainage channels controlled by Gates P1, P2, S1, S2, V1, and V2 to maintain water levels.
	Micro Water Management System	5 Secondary Gates M, O, Q, and S are opened at water levels above + 1.1 m and closed at water levels below + 0.5 m.

Based on the simulation results in the secondary channel Q Block A5, the average water level in the secondary channel in the dry season is + 0.6 m to + 0.7 m. In the rainy season, the average water level elevation increases with the influence of rainfall, which is at + 1 m to 1.1 m. The average water table elevation in the secondary canal was compared to the optimal operation and maintenance requirements of the gate, which keeps the minimum water table at 60 cm below the ground surface elevation in the dry season and the maximum water table at 10 cm above the irrigation water requirement in the land. Water quantity dynamics in the tertiary block based on the operation and maintenance in the dry and wet seasons is shown in Figures 13 and 14.

Hydraulic Simulation of Operation and Maintenance on Water Quality

Operation and maintenance of irrigation networks also affect water quality, as represented by the pH parameter. Changes in water quality represented by the pH value in the canal can be

obtained by installing a telemetry monitoring device that records the condition of the pH parameter during both the rainy and dry seasons, as shown in Figures 15 and 16 (Zevri, 2023).

The pH value data obtained from the telemetry monitoring tool in the dry season is at level 3 which is not too influenced by tidal fluctuations. Rainfall that occurs in the rainy season can increase the pH value to 5. Based on these two conditions, it becomes the basis for the channel operation and maintenance optimization simulation based on Table 8 to maintain the water quality values shown in Figures 17 and 18.

Based on the graph above, it shows that the operation and maintenance optimization of the Dadahup Lowland Irrigation Area in the dry season can reach pH level 3 and increase to level 5 in the rainy season. The increase in water quality, namely pH, can reach a level of 4.5 with the influence of rainfall and decreases to level 2 in the dry season (Zevri et al., 2022).

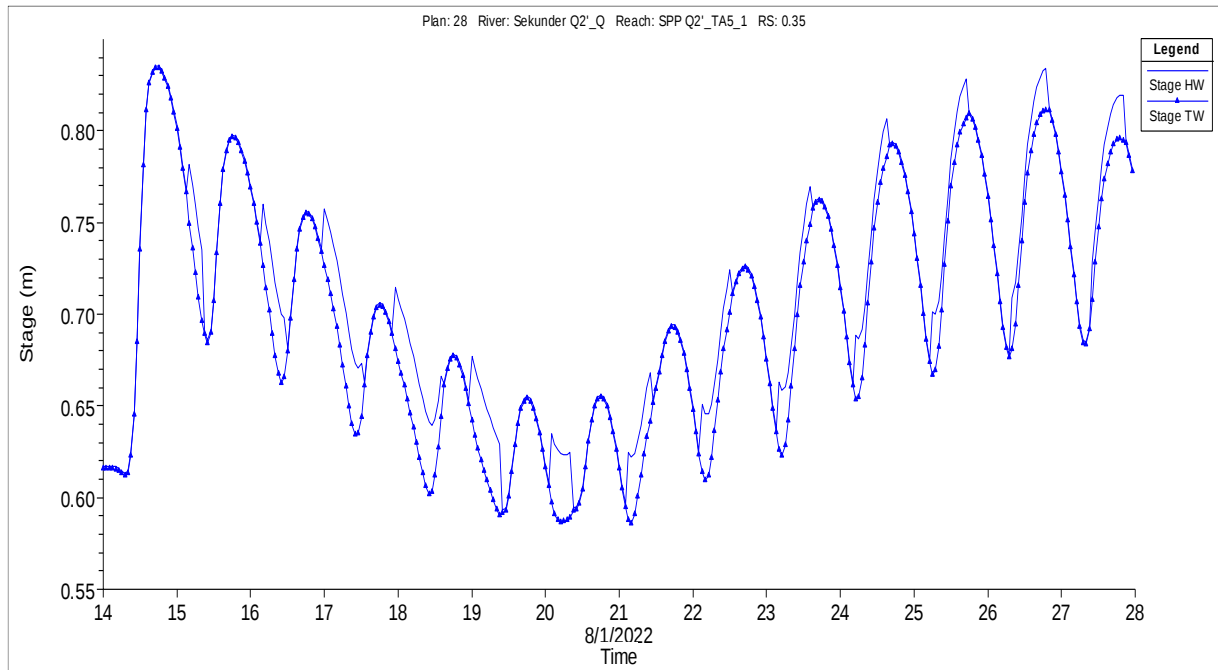


Figure 11 Simulation results of water level dynamics optimization of operation and maintenance of secondary channel Q block A5 Dadahup in the dry season

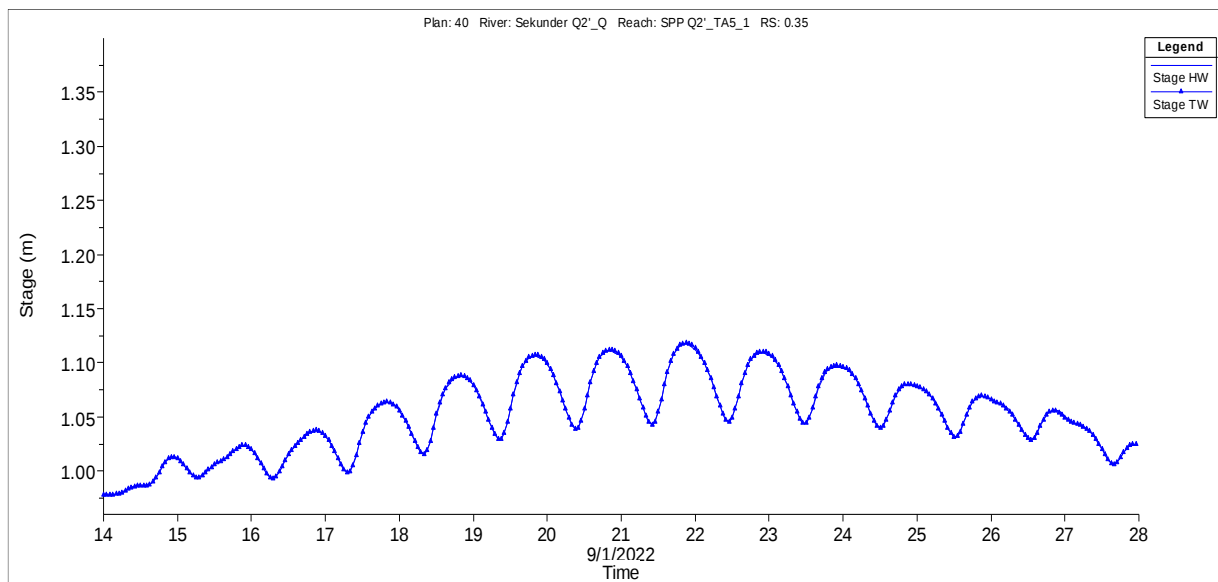


Figure 12 Simulation results of water level dynamics optimization of operation and maintenance of secondary channel Q block A5 in the rainy season

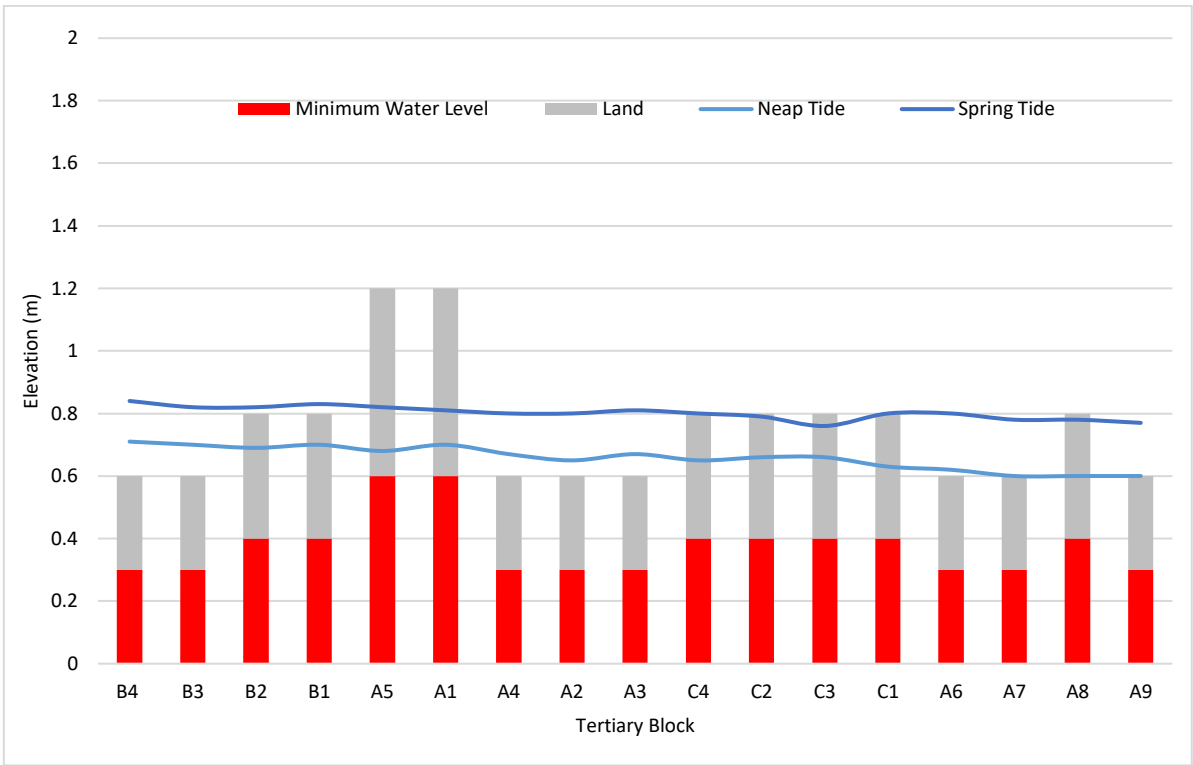


Figure 13 Water quantity dynamics in tertiary blocks based on operation and maintenance optimization in the dry season

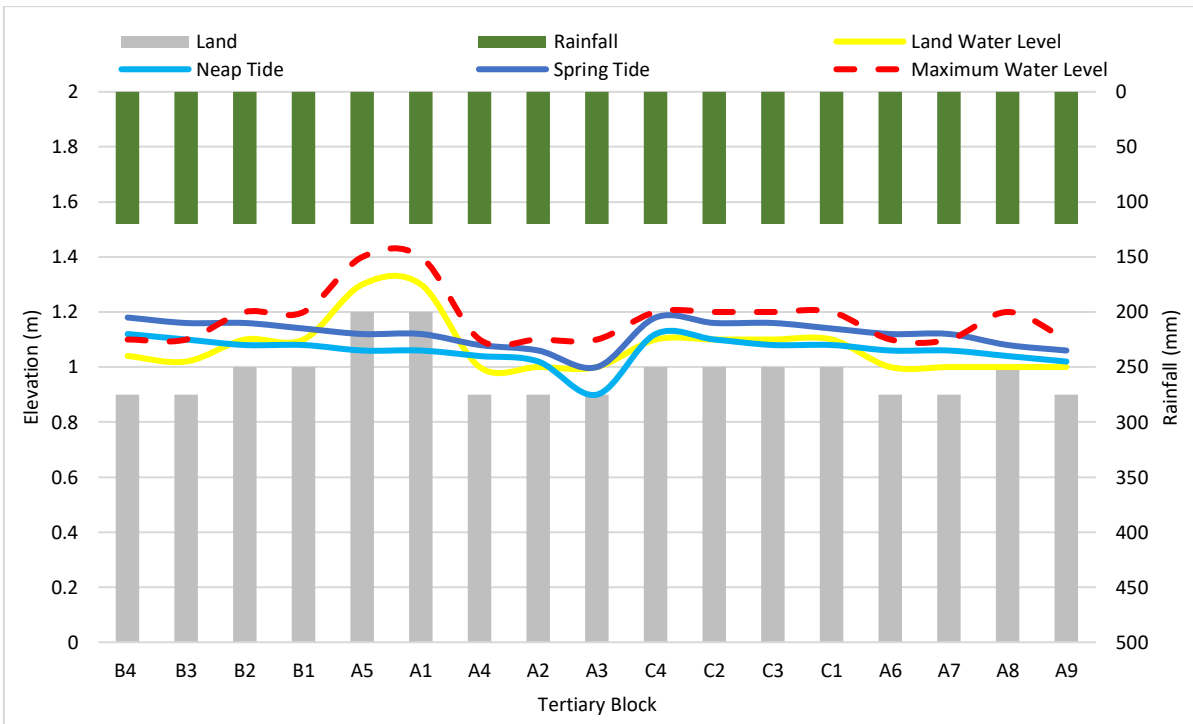


Figure 14 Water quantity dynamics in tertiary blocks based on operation and maintenance optimization in the rain season

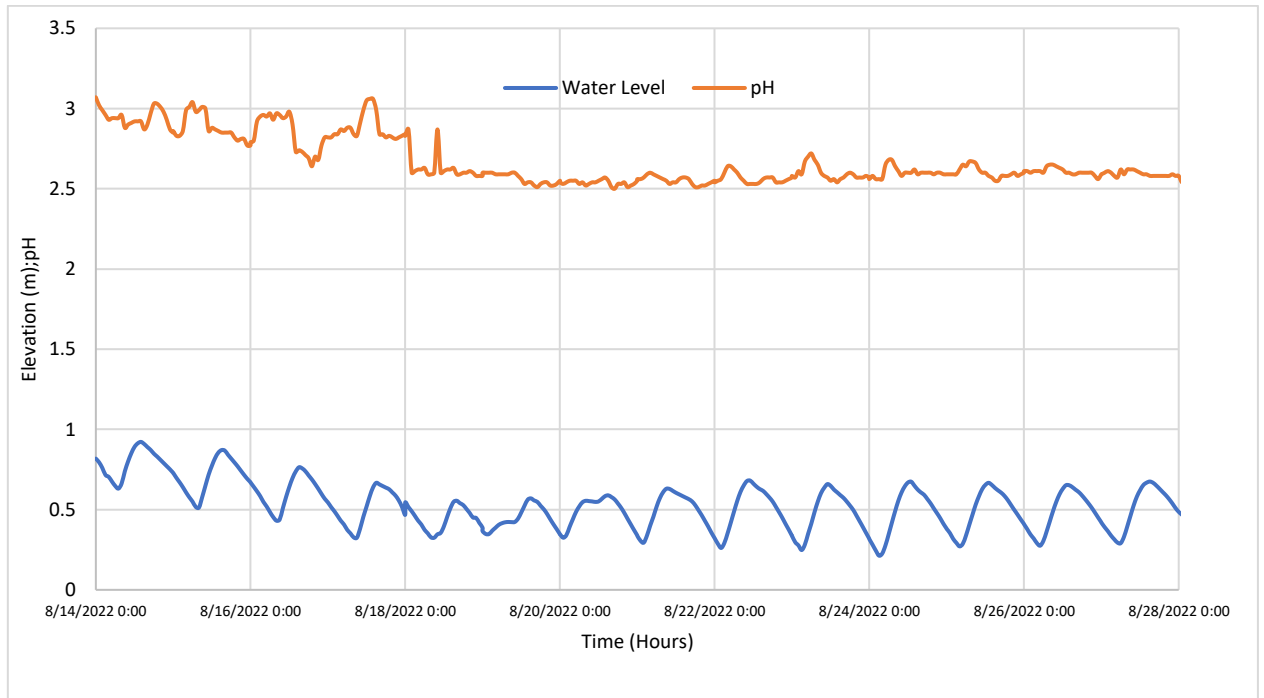


Figure 15 Dynamics of pH values in the dry season at Dadahup Lowland Irrigation Area

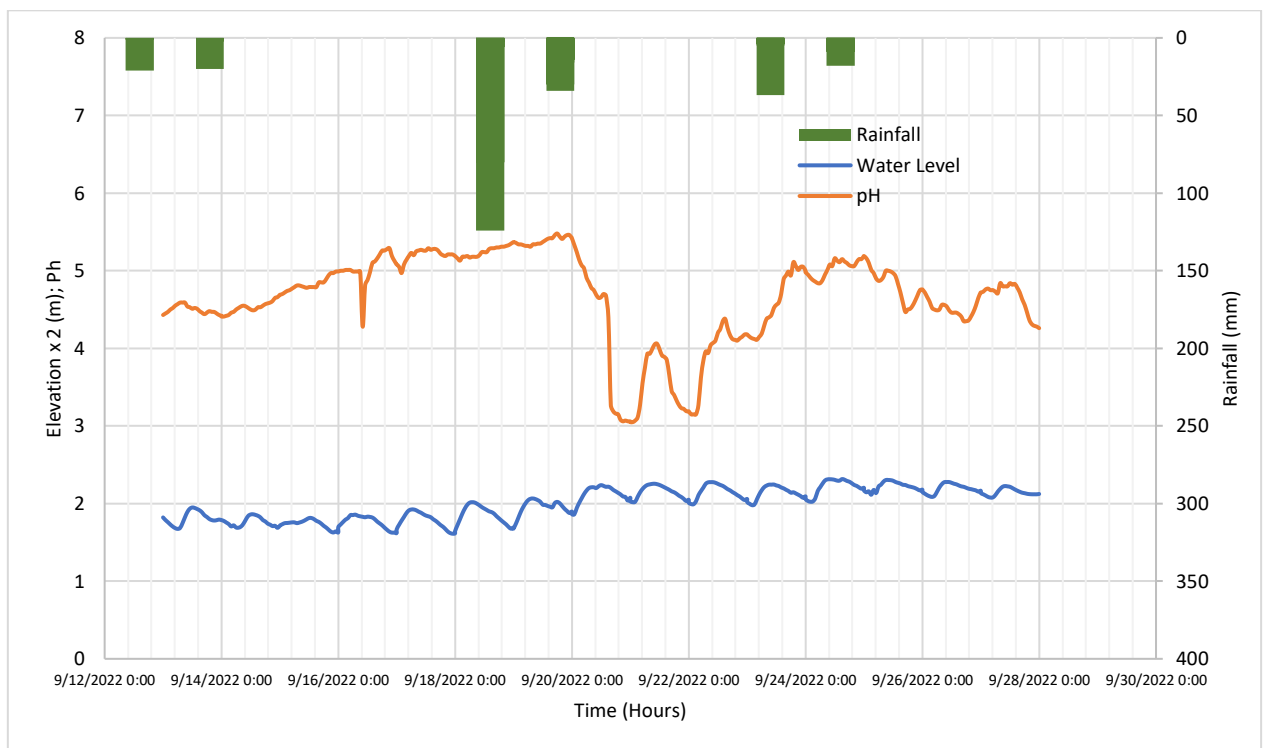


Figure 16 Dynamics of pH values in the rainy season at Dadahup Lowland Irrigation Area

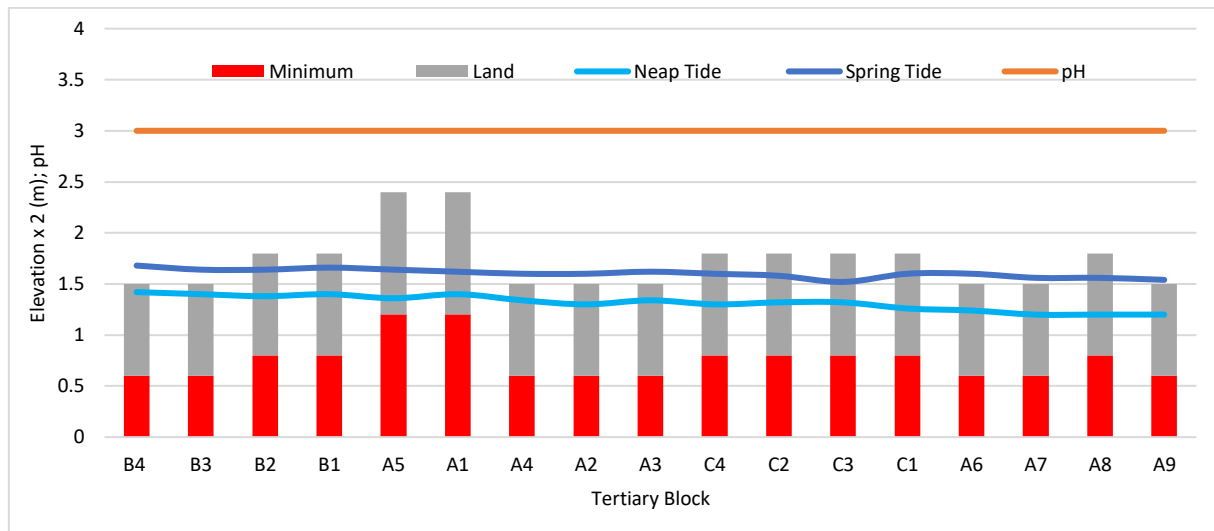


Figure 17 Water quality dynamics in tertiary blocks based on operation and maintenance optimization in the dry season

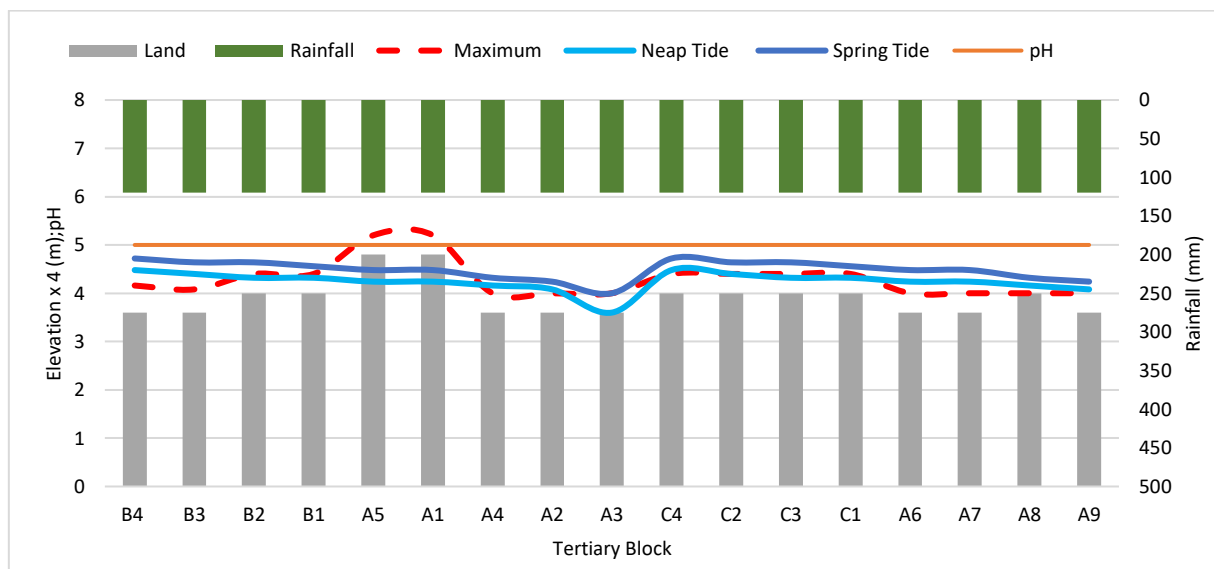


Figure 18 Water quality dynamics in tertiary blocks based on operation and maintenance optimization in the rainy season

CONCLUSIONS

The optimization offers valuable insight for operation and maintenance of lowland irrigation area. In this study, the optimization suggests gates operation in primary and secondary sluice gates should be opened at water level elevations above + 0.5 m in the dry season as supply and water level elevation + 1.1 m in the rainy season as drainage. Primary and secondary sluice gates are closed at water levels below + 0.5 m to maintain water levels and water quality. This arrangement results in an appropriate water level for both rainy season dan

dry season. Similar optimization strategies can be applied to various other lowland irrigation areas to support optimal its agricultural productivity.

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