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Water Balance and High Levels of Water Channel in Belanti I Tidal Irrigation Swamp Central Kalimantan Province

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ABSTRACT: *The potential of tidal swamps in Indonesia is 39.40 million ha. From that tidal swamp area, only 2 million ha have been developed for agricultural and residential cultivation. One swamp area that has considerable potential is the 3,600 ha Rawa Belanti I Irrigation Area in Central Kalimantan. In order to assist the government in developing swamps as one of the agricultural intensification efforts in Kalimantan, modeling is needed to find out the pattern of water movement in the Rawa Belanti I Irrigation Area and how the water balance is to see the problems at the site and it's done to try to provide some solutions to those problems. The HEC-RAS program is used to model water conditions and evaluate water balance in the Rawa Belanti Irrigation Area I. Input of HEC-RAS data uses tidal observational data measured on the upstream primary channel. Program simulations are carried out following the time of tidal data collection (June II - July I). Primary and secondary channel modeling is done separately to minimize errors, where the results of modeling on the primary channel in the form of water level are then used as boundary conditions when modeling secondary channels. Evaluation of water balance is done by comparing irrigation water needs with the discharge of the modeling results and looking at the water level from primary to secondary channels whether it can flow downstream of the channel. The results of the evaluation of the water balance show that the discharge in the primary channel DIR. Belanti I in the period June II and July I is sufficient for the water needs of each secondary channel. However, at low tide, water cannot flow to the secondary canal and at high tide, there is a possibility of flooding, especially in secondary channels close to the Kahayan River, where the potential for flooding is quite large. The right solution is needed so that irrigation water needs can always be fulfilled and runoff does not damage the rice field area. One of them can be done by using sluice gates in each secondary channel optimally, pumping at low tide, and building embankments on the banks of primary and secondary channels.*

Keywords: *Tidal Irrigation, HEC-RAS, Water Balance, water level.*

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I. PRELIMINARY

The potential area of swamps in Indonesia is around 162.40 million hectares, consisting of 39.40 million hectares of tidal swamps (24%) and around 123 million hectares of non-tidal swamps (75%). This swamp land is spread across several islands, especially the islands of Borneo, Sumatra, and Papua. From the total potential of tidal swamp land, only about 2 million hectares of tidal swampland has been reclaimed for the development of agricultural cultivation and settlements.

Low soil fertility and high risks of pests are the causes of the many undeveloped swamp irrigations. In addition, the inappropriate management of irrigation networks is also a limiting factor for irrigation development. Efforts to develop swamps in addition to being carried out by the government are also carried out by local residents. This is because food needs to increase continuously. Efforts to fulfill food needs can be done in various ways, one of which is the agricultural extensification.

Agricultural extensification is an effort to increase agricultural output by expanding new agricultural lands, such as clearing forests, shrubs, areas around swamps, and untapped agricultural areas. Agricultural extensification is mostly carried out in sparsely populated areas such as outside Java, especially in some transmigration destinations, such as Kalimantan.

The swamp area in Central Kalimantan is estimated to be 4.3 million ha consisting of 0.7 million ha of tidal swamps and 3.6 million ha of non-tidal swamps. One of the locations of tidal swamps with considerable potential is the Rawa Belanti I Irrigation Area with a total area of 3,600 ha located in Pulang Pisau Regency. The Pulang Pisau District can be seen in Figure 1. In order to assist the government in developing swamps as one of the agricultural intensification efforts in Kalimantan, modeling is needed to find out how the water movement patterns in the Rawa Belanti I Irrigation Area and how the water balance is to see problems at the site and try to provide several solutions that can overcome these problems.

This study attempts to model the condition of the Rawa Belanti I Irrigation Area in the 1-dimensional HEC-RAS program to see how the physical conditions of the channel and the water system DIR Belanti I, water level, and water balance. It is hoped that the results of this study can be maximally utilized for the development of the Rawa Belanti I Irrigation Area and can support efforts to meet food needs by the government.

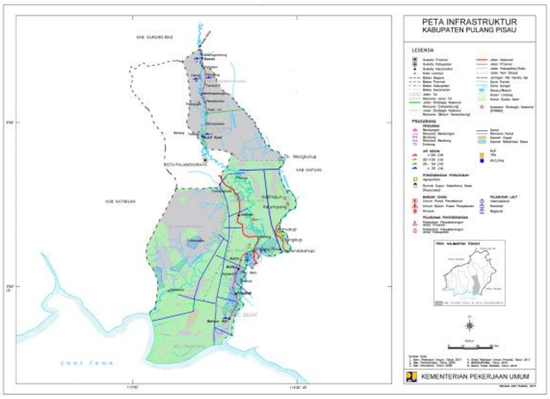


Figure 1 Pulang Pisau Regency, Central Kalimantan (Source: Ministry of Public Works, 2012)

II. RESEARCH METHODS

The analysis to be carried out in this study is a hydrological analysis which includes analysis of the effect of rain stations, rainfall analysis, reliable discharge analysis, and analysis of water requirements. Tidal data on the upstream primary channel will be used as data input for the water management system model in the Rawa Belanti Irrigation Area which is evaluated using the HEC-RAS program.

- **Research Sites**

The research location is in the Rawa Belanti I Irrigation Area, Pulang Pisau Regency, Central Kalimantan Province (Figure 2).

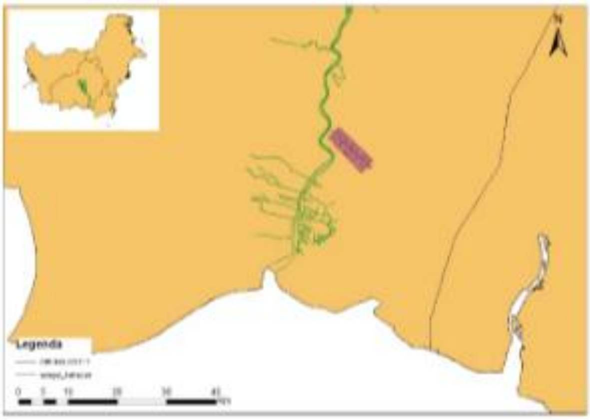


Figure 2 Research Sites

- **Data Collection**

The data used in this study are hydrological data (rainfall, tidal observation data, and climatology data), and profile data of irrigation channels.

Daily rainfall data was obtained from 7 rain stations (Figure 3) which were located around the research sites. Tidal observation data is taken on the upstream and downstream of the primary channel (Figure 4) which is taken on June 24, 2019, at 7:00 p.m. until July 9, 2018, at 18:00. Whereas climatology data (10 years of data) were obtained from Mantaren station closest to the research location.

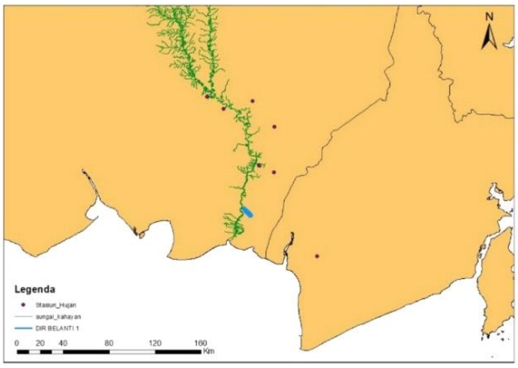


Figure 3 Distribution of rain gauge stations

Figure 4 Tidal observation points in the primary channel of DIR Belanti I

The sketch of observations of tides in the primary channel can be seen in Figure 5. Where point 0 is at +8 m elevation of the primary channel.

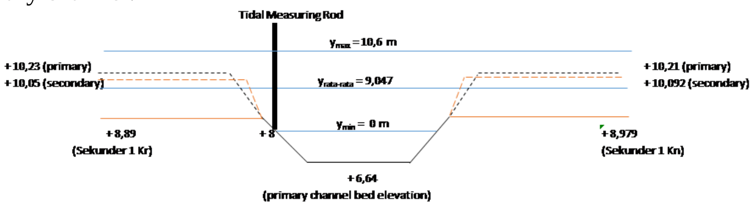
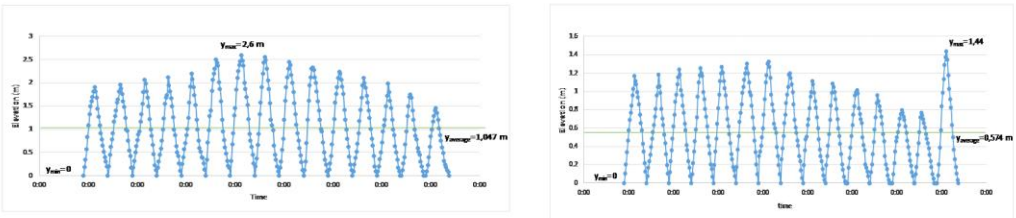


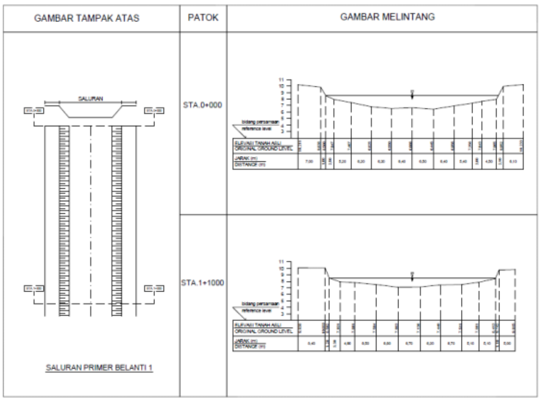
Figure 5 Sketch of tidal observations



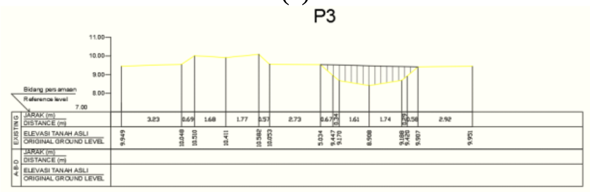
(a) (b)

Figure 6 Graph of tidal primary channels (a) upstream; (b) downstream

Channels in Belanti I DIR are primary and secondary channels (50 right secondary channels and 50 left secondary channels). Cross-section of the primary channel is taken at 11 measurement stations which are spread from upstream to downstream along 11 km. While the cross-section of secondary channels is taken at 3 measurement points, namely P1 (downstream), P2 (middle), and P3 (upstream) in each secondary channel, with the right secondary channel length of 2000 m and the left secondary channel length of 1600 m.



(a)



(b)

Figure 7 Cross-section (a) primary channel; (b) secondary channels

- **Hydrological Analysis**

The hydrological analysis that was done is rainfall analysis, reliable discharge analysis, and analysis of water requirements.

Rainfall analysis uses the polygon Thiessen method to determine the effect of the rain gauge station and reciprocal method to fill in the empty rainfall.

$$P_x = \frac{\frac{P_A}{d_{XA}^{2}} + \frac{P_B}{d_{XB}^{2}} + \frac{P_C}{d_{XC}^{2}}}{\frac{1}{d_{XA}^{2}} + \frac{1}{d_{XC}^{2}} + \frac{1}{d_{XC}^{2}}}$$

Where:

PA, PB, PC= Precipitation data from stations recorded A, B, C

dXA = Distance between station X and reference station A

dXB = Distance between station X and reference station B

dXC = Distance between station X and reference station A

The reciprocal method takes into account the distance between rain gauge stations which is analyzed by the reference station used. Whereas for empty rainy day data input will be done with a linear approach from the graph of the relationship of rainy days with monthly rainfall based on wet and dry seasons.

Reliable discharge analysis was calculated using the FJ Mock method. Reliable discharge is needed to determine the minimum flow of the river for possible specified fulfillment so that it can be used for irrigation. This method takes into account rainfall data, evapotranspiration and hydrological characteristics of the river basin.

Evapotranspiration is calculated using the Penman Modification method as follows:

$$Eto = c \times Eto^*$$

$$Eto^* = W\,(0.75Rs - Rn1) + (1 - W) \times f(u) \times (ea - ed)$$

Where:

Eto : Potential evapotranspiration

W : Factors related to temperature and regional elevation

Rs : Shortwave radiation

Ra : Shortwave radiation that meets the broad atmospheric limit (angot number) which is affected by the location of the latitude of the area

Rn1 : Long wave clean radiation

f(t) : Temperature function

f(ed) : Steam pressure function

f(n/N) : Brightness function

f(u) : Function of wind speed at an altitude of 2 m

u : Wind speed

(ea-ed) : The difference in vapor pressure is saturated with actual steam
ed : ea . RH
RH : Relative air humidity
ea : saturated vapor pressure
c : Penman correction number

The balance of water on the ground is influenced by the amount of water entering the soil surface and the condition of the soil itself, the data needed is:

- P - Et, changes in water that will enter the soil surface
- Soil storage, changes in the volume of water held by the soil which depends on (P - Et) and storage soil the previous month
- Soil Moisture, the volume of water to moisturize the soil which depends on (P - Et), soil storage, and soil moisture the previous month.
- The capacity of soil moisture, the volume of water needed to achieve soil moisture capacity
- Water surplus, the volume of water that will enter the soil surface, namely WS = (P - Et) + Soil Storage, and 0 if (P - Et) <Soil Storage.

The amount of Ground water storage depends on water balance and soil conditions, with the following equation:

$$I_n = Water\ Suprplus \times I$$

$$V = k \times V_{(n-1)} + 0{,}5(1+k)I_n$$

$$A = V_n - V_{n-1}$$

Where:
I_n : Infiltration of the volume of water entering the soil
V : Groundwater volume
dVn : Changes in the volume of groundwater in the n-th month
$V_{(n-1)}$: Volume of groundwater (n-1)
I : Infiltration coefficient
A : Monthly storage volume

Discharge on the river is calculated by:

- Base Flow = Infiltration - changes in groundwater storage (mm / mo)
- Direct Run Off= water surplus – infiltration (mm)
- Storm Run Off:

If CH ≥ 200 mm = 0
CH < 200 mm = Percentage Factor x CH

- Run Off = Base Flow + Direct Run-Off + Storm Run-Off

Analysis of the need for clean water in rice fields (NFR) is influenced by NFR factors such as land preparation, consumption, flooding, irrigation efficiency, percolation, and infiltration by calculating effective rainfall (Re).

$$NFR = Etc + P + WLR - Re$$

Where:
NFR :Irrigation water needs in rice fields (l / sec / ha)
DR : Water requirements at the picking gate (l / s / ha)
Etc : Consumptive use (mm / day)
P : Percolation
WLR : Replacement of water layer (mm / day)
Re : Effective rains
A : Area of planned irrigation area (ha)
e : Irrigation efficiency

The results of FJ Mock discharge results must be calibrated with measured discharge in the field to determine FJ Mock parameters such as exposed surface (m), infiltration coefficient, recession constant (k), and percentage factor. The calibration results were analyzed using the NSE (Nash-Sutcliffe Model Efficiency Coefficient) method, where if the NSE value approaches 1 then the model is considered accurate.

Where:
Q_o = measured average discharge

Q_m = discharge analysis results of FJ Mock calibration
Q_{ot} = measurable discharge at time t

- **Tidal Analysis**

The tidal analysis is carried out to determine the water level of the plan and find out the type of tides that occur and predict sea level fluctuations. Tidal analysis in this study uses the Least Square method. The stages of analysis are as follows:

- Defining observation matrix [L], in the form of tidal observations in 360 fields (15 days).
- Defining the design matrix [A], to find the value of 9 tidal constants that are sought, which are 19 parameters, namely Z0, A1, A2, ..., A9 and B1, B2, ..., B9. The number of lines of the design matrix is 360 lines.
- Calculating parameter values from calculations [L] and [A]
- Calculating the observation matrix after being corrected by the formula V = A X –L, while the observation matrix after correction is La = L + V.
- Calculating amplitude (Hn)
- Calculating phases (gn)

Of the 9 tidal components that have been obtained from harmonic analysis, it can be seen that important water levels can be seen in Table 1.
Calculation of Formzahl (F) is done to get the type of tide that occurs with the equation as follows:

Where:
AO : Component amplitude O1
AK1 : Component amplitude K1
AM2 : Component amplitude M2
AS2 : Component amplitude S2

Table 1 Important water level elevation formulas

Water Level Elevation	Formula
HHWL (Highest High Water Level)	$Z_0 + (M_2 + S_2 + K_1 + O_1)$
MHWL (Mean High Water Level)	$Z_0 + (M_2 + K_1 + O_1)$
MSL (Mean Sea Level)	Z_0
MLWL (Mean Low Water Level)	$Z_0 - (M_2 + K_1 + O_1)$
LLWL (Lowest Low Water Level)	$Z_0 - (M_2 + S_2 + K_1 + O_1)$

- **Modeling on HEC-RAS**

Existing conditions in the Rawa Belanti I Irrigation Area are modeled on the HEC-RAS 5.0.1 program for evaluation. The DIR I BELANTI scheme can be seen in Figure 8.
Modeling DIR Belanti I channels in HEC-RAS is carried out separately between the primary and secondary channels to minimize errors that occur due to the number of channel branches (total 100 secondary channels) in the DIR I BELANTI. At HEC-RAS, sta 0 is downstream.

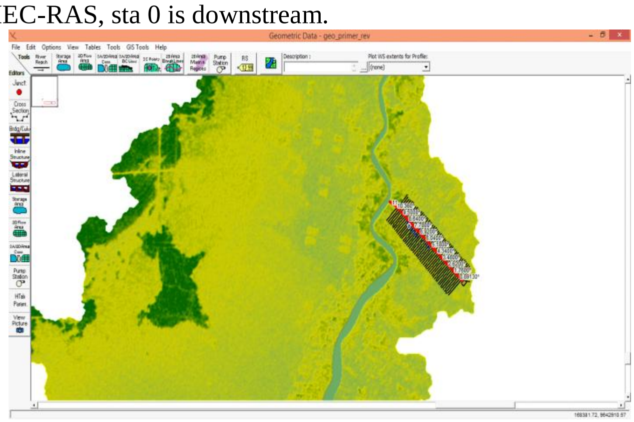


Figure 8 Geometry DIR I BELANTI on the HEC-RAS

Modeling is done using an unsteady flow analysis model. The input data in the upstream primary channel condition (STA 11) is tidal data, so the type of boundary condition used is the stage hydrograph. while the downstream channel (sta 0) uses a type of normal depth boundary condition, that is by entering the channel slope value. The same is done when modeling on secondary channels.

Running model in HEC-RAS use unsteady flow analysis, with simulation time starting on June 24, 2018, at 7:00 p.m. until July 9, 2018, at 18:00 (according to tidal data) with calculation intervals every 1 minute.

- **Validation Model**

Validation is needed so that the accuracy of the results of the modeling can be known accurately. The parameter that can be used to carry out the validation process is the water level elevation on the channel measured in the field with the results of the analysis on the HEC-RAS 5.0.1 program.

Validation is done using the root mean square error (RMSE) method. RMSE is calculated by squaring the error divided by the amount of data (= average), then rooted. If the RMSE value approaches 0, the model is considered good or can represent the existing conditions in the field.

- **Water Balance Evaluation of DIR Belanti I**

In this research, an evaluation of the water balance and the existing conditions of the Rawa Belanti I Irrigation Area using the results of modeling from the HEC-RAS program was done. The input of hydrological data in this model is the water level elevation in the upstream channel from the results of tidal measurements.
Evaluation of the water balance is done in 2 ways, which are:

- Comparing the needs of irrigation water with discharge in the channel (results of HEC-RAS modeling)
- Comparing the water level elevation on the primary channel resulting from HEC-RAS modeling with secondary channel elevation to see whether water can rise to the secondary channel and flow downstream of the secondary channel.

III. RESULTS AND DISCUSSION

- **Overview of Research Sites**

Pulang Pisau Regency generally includes tropical and humid regions with temperatures ranging from 20oC - 35.8oC. As an area with a tropical climate, the Pulang Pisau Regency area receives solar radiation above 50% on average. Most precipitation falls in October - December, and January - March which ranges from 2,000 - 3,500 mm every year, while dry months fall in June - September.
The topography of Pulang Pisau Regency in the southern part consists of coast/coast, swamps with a height of 0–10 meters above sea level which has an elevation of 0-8 degrees and influenced by tidal water as well as an area that has a large flood intensity.

In the hydro topographic classification, DIR Belanti I belongs to category A. Tidal swamp land elevations at the location of DIR Belanti I generally revolve around the full tidal water level of the average rainy season at the nearest river location with an average height of 1 m to 3 m above average sea level (MSL-Mean Sea Level).

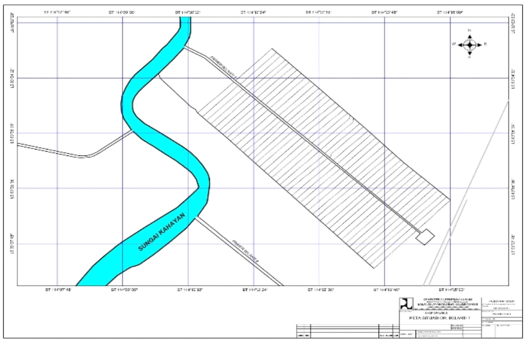


Figure 9 Scheme of DIR Belanti I (Source: BWS Kalimantan II)

The network water management system in DIR Belanti I uses a "comb system" (Sisir Sistem). The increase in sea level will greatly affect this irrigation system because it will cause changes in hydro-topography and land suitability. The pool at the study location is not functioning. In the DIR Belanti I region all the channels use the beam skid gate, but the use of the sluice has not been fully utilized.

- **Hydrological Analysis**

The results of Thiessen Polygon (Figure 10) indicate that the stations that affect the DIR Belanti I are Mantaren Station and Maliku Station.

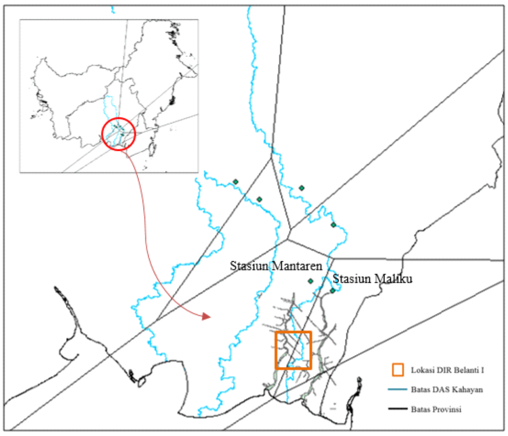


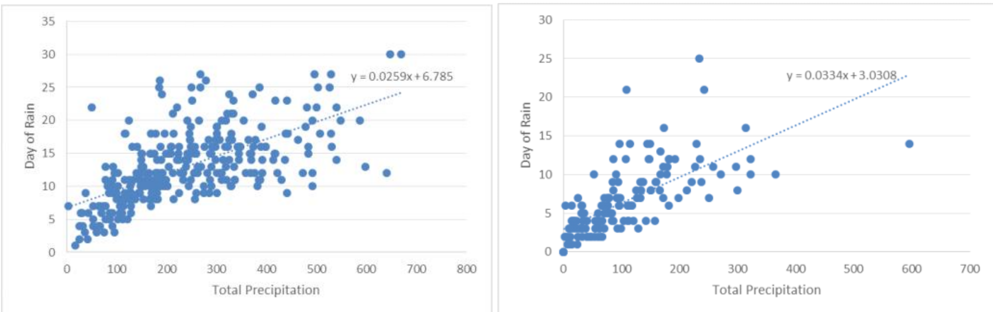
Figure 10 Thiessen polygon

Table results of data input in empty rainfall data at Mantaren and Maliku stations and then analyzed by polygon Thiessen analysis can be seen in Table 2.

Table 2 Monthly CH (mm)

Tahun	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	432.6	176.3	469.9	493.2	56.4	131.6	28.4	85.1	33.5	69.2	113.3	177.8
2008	39.1	81.0	224.1	107.9	64.3	53.8	29.8	81.6	97.9	92.1	135.4	261.1
2009	119.4	144.1	211.6	115.9	81.3	9.7	21.3	2.7	23.8	83.1	156.0	136.1
2010	299.7	140.1	333.1	174.6	132.3	164.0	144.8	36.4	17.5	263.2	110.3	159.4
2011	92.0	38.1	109.0	93.7	28.7	38.1	14.5	11.8	41.3	332.1	154.7	537.3
2012	186.9	192.8	202.2	270.4	72.1	80.4	148.4	50.7	18.7	254.3	257.1	355.5
2013	255.2	307.0	386.0	244.2	303.3	193.5	91.1	108.4	170.4	90.3	304.6	128.2
2014	42.1	247.5	341.8	136.4	131.0	82.8	40.0	132.8	13.8	85.4	158.6	393.9
2015	274.8	259.1	333.6	97.0	149.7	149.7	21.6	0.1	8.3	27.0	129.3	258.5
2016	274.9	409.8	329.2	343.2	186.8	105.0	169.6	18.8	223.9	281.0	257.6	249.5
2017	260.9	138.1	91.9	250.6	236.0	297.1	119.0	197.2	130.7	245.1	343.5	377.9

To fill an empty rainy day because of the unavailability of data, an approach was taken by looking for a relationship between rainy days and the rainfall recorded on the existing stations. The relationship between rainy days and rainfall at the rain gauge station is divided into two seasons, namely the wet season (January-May & October-December) and the dry season (June-September).



(a) (b)

Figure 11 Relation between rainy days and rainfall (a) wet season; (b) dry season

With the equation obtained from the graph above, data obtained from the rainy days of Mantaren and Maliku stations were then averaged in Table 3.

In calculating the reliable discharge, the FJ Mock method requires Calibration with the observation station discharge data to determine the required parameters such as exposed surface (m), infiltration coefficient, recession constant (k), and percentage factor.

Table 3 Rainy Days

Tahun	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	17	14	14	15	8	10	5	5	5	11	14	12
2008	10	12	18	14	6	7	9	8	7	10	13	23
2009	18	13	16	9	7	4	4	3	2	8	15	18
2010	17	13	18	15	9	13	13	10	9	16	13	15
2011	16	9	13	12	6	5	2	3	6	11	13	23
2012	12	19	15	17	9	10	13	6	12	16	22	22
2013	22	22	25	21	19	19	16	11	12	13	13	23
2014	18	19	24	13	9	8	4	9	1	5	11	21
2015	25	19	23	11	11	8	5	2	6	6	10	11
2016	21	21	16	19	16	8	7	4	11	15	14	18
2017	17	12	14	13	16	13	11	12	12	13	16	17

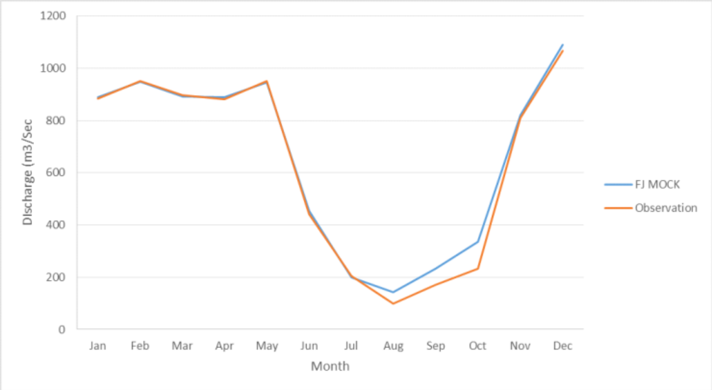


Figure 12 Comparison of FJ Mock discharge and measured discharge

The NSE value of the analysis is 0.988 so that the results of the FJ Mock discharge calibration are considered to be appropriate and resemble the measured discharge in the field. The reliable discharge graph of the analysis using parameters that have been calibrated can be seen in Figure 13.

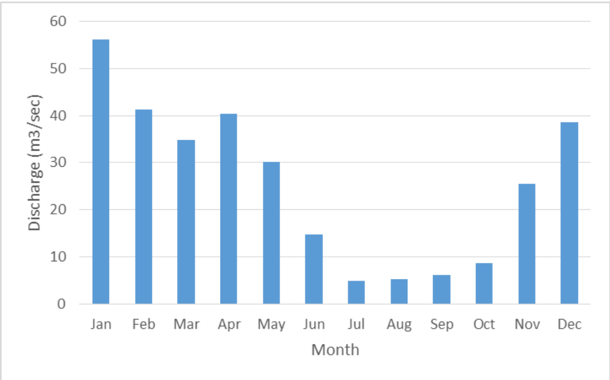


Figure 13 80% Reliable discharge

As can be seen in the graph above, the reliable discharge in July, August, September, and October is less than 10 m^3/second. While the largest is in January at 53.56 m^3/second. This can be one of the references in choosing alternative planting times so that the water requirements in DIR Belanti I can always be fulfilled.

Analysis of plant water demand was carried out using effective rainfall analyzed from ½ monthly rainfall. The highest NFR value is the value of NFR in the alternative I and percolation value of 3. However, if I use alternative I with percolation value 3 water demand in October I cannot be fulfilled. So that alternative II is used with the planting period beginning in October II. With the area of rice fields in DIR Belanti I of 2400 ha, the water demand is 2.32 m^3/sec. The water balance in the DIR Belanti I can be seen in Figure 14.

From the water balance graph, it can be seen that the water supply can meet the water demand in the DIR Belanti I throughout the year. From November to May, water is abundant with a flow rate of 25-56 m^3/sec and a surplus water balance of 20 - 49 m^3/sec. From June to October, the water is abundant with 4.8 - 15 m^3/second discharge and surplus water balance of 2.5 - 10 m^3/second.

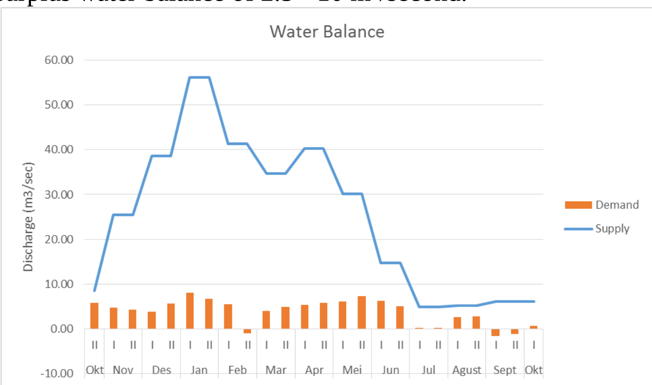


Figure 14 Graph of water balance

- **Tidal Analysis**

From the results of tidal analysis using the Least Square method, the important water level elevation is obtained as follows:

Table 4 Important water level

Water Channel Elevation	Elevation (m)
HHWL (Highest HighWater Level)	4,14
MHWL (Mean High Water Level)	3,81
MSL (Mean Sea Level)	1,04
MLWL (Mean Low Water Level)	-1,74
LLWL (Lowest Low Water Level)	-2,07

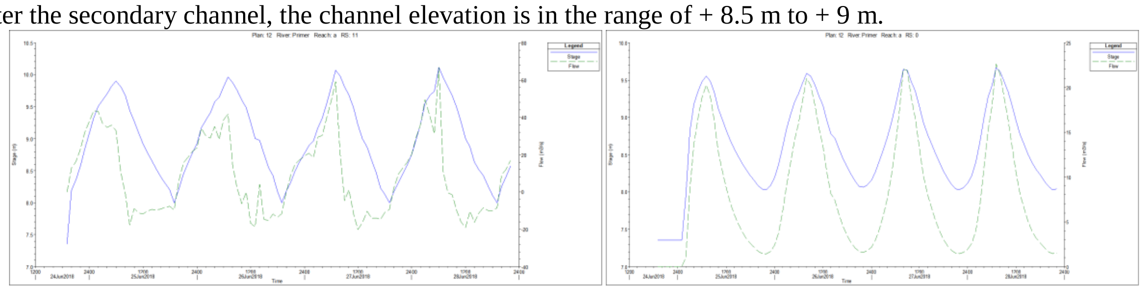
The Formzall number calculated is 6.11. The Formzall number shows the type of tide in DIR Belanti I is a diurnal type or a single daily tide, wherein 1 day there is 1-time tide and 1-time low tide. The tidal period is 24 hours 50 minutes.

- **Modeling DIR Belanti I on HEC-RAS**
- **Primary Channel Modeling DIR Belanti I**

Modeling on HEC-RAS is done by carrying out simulations of the primary channel with tidal data input observations carried out upstream of the primary canal on June 24, 2018 - July 9, 2018 (360 hours).

From the results of the primary channel modeling, it is known that at the highest tide, water in the primary channel is likely to run out of the primary channel. Upstream of the primary channel, the highest elevation of the water level is at + 10.6 m while the channel elevation of the channel is at + 10 m. While the highest elevation of the water level in the primary channel downstream is at +10.06 m with the river lip elevation at + 9.6 m.

At low tide water is still available but the water level is not high enough to be able to enter the secondary channel. Water upstream of the primary channel at low tide is at + 8 m elevation so that it cannot enter the secondary channel, the channel elevation is in the range of + 8.5 m to + 9 m.

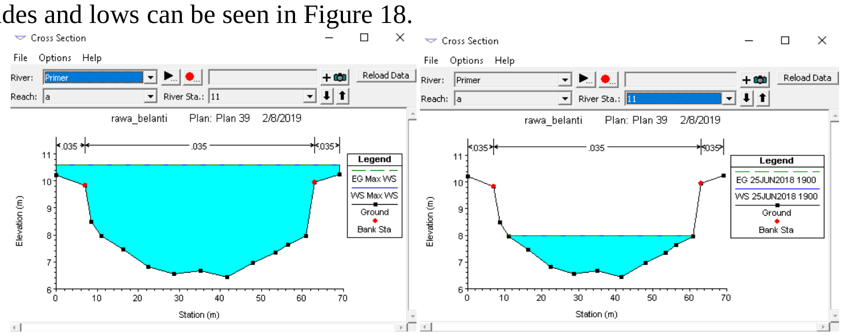


(a) (b)

Figure 15 Graph of water level and primary channel discharge (a) upstream; (b) downstream

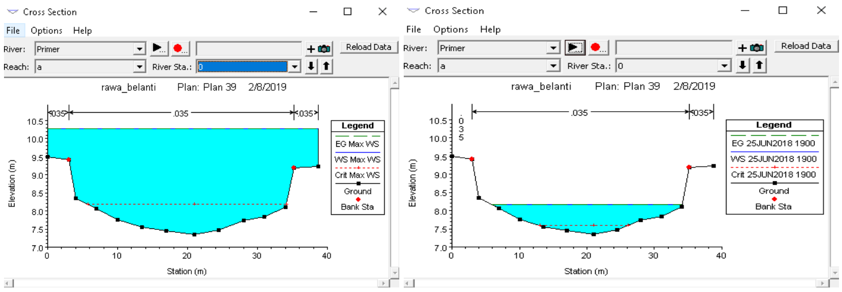
Graphs of water level and discharge at the primary channel indicate compatibility between each other, where if the discharge is large then the water level will rise and vice versa. The tidal graph pattern in the upstream channel has followed the tidal graph pattern in tidal observation data in the field, but the discharge graph in the upstream channel even though it has followed the tidal pattern, the flow rate is still unstable. Things like this sometimes occur in unsteady flow simulations because flow data is not compatible with channel geometry data, so the analysis becomes non-convergent.

The cross-section in the upstream and downstream of the primary canal as a result of the HEC-RAS model when the lowest highs and lows can be seen in Figure 16 and Figure 17. The long-section in the primary channel during tides and lows can be seen in Figure 18.



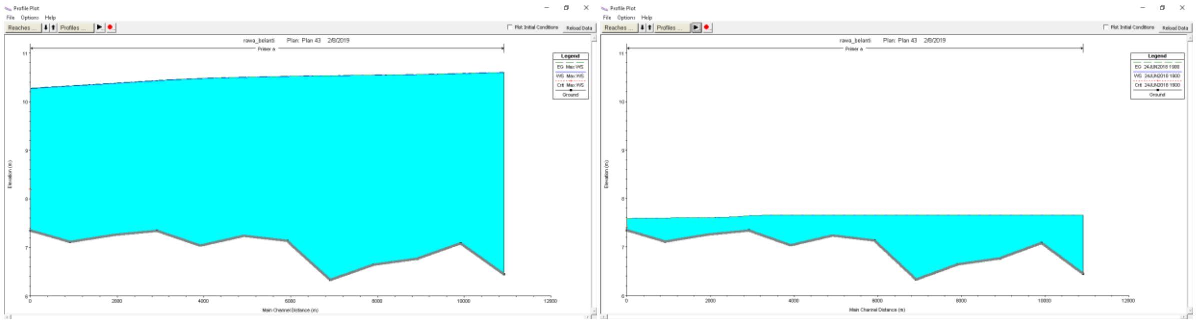
(a) (b)

Figure 16 Upstream conditions of the primary canal at (a) high tide and (b) low tide



(a) (b)

Figure 17 Condition of the primary channel downstream during (a) high tide and (b) low tide



(a) (b)

Figure 18 Long-section water level elevation of the primary channel (a) high tide; (b) low tide;

The results of the water level in the primary channel downstream are validated with observational tidal data in the downstream primary channel at the same time to see the accuracy of the modeling results.

- **Model Validation**

The validation of the HEC-RAS model is done by comparing observations of tides (downstream) in the primary channel downstream with water level data from the results of modeling on the HEC-RAS in the downstream primary channel. Comparison of the water level can be seen in Figure 19.

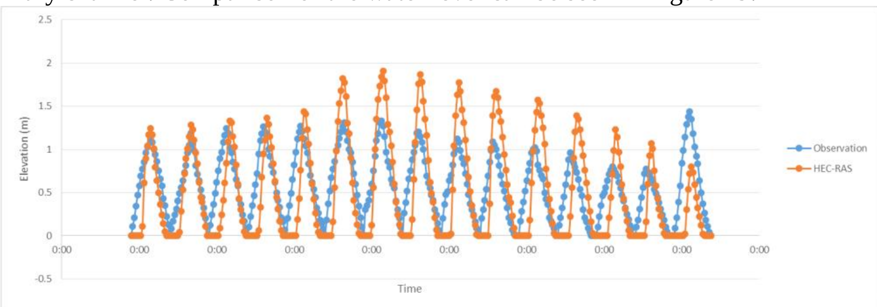


Figure 19 Tidal graph downstream of the primary channel (HEC-RAS vs. Observation)

From the graph above, it can be seen that the tidal pattern in HEC-RAS is in accordance with the pattern of tidal data observations, but there are differences in the water level at the time of the tide on certain days. The difference in elevation ranges from 0 to 0.5 m. This may be caused by changes in the dimensions of the modeling channel cross-section that is still not in accordance with the existing channel.

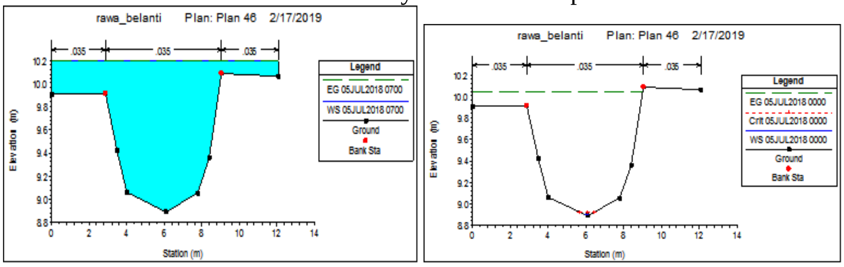
From the RMSE calculation to test the model, the RMSE value of 0.39 is obtained where the data will be considered more accurate if it approaches the value of 0. Judging from the large data distribution, based on the RMSE test the results of the HEC-RAS modeling are considered feasible so the results of modeling (water level) can be used as a boundary condition in secondary channel modeling.

- **Secondary Canal Modeling DIR Belanti I**

Secondary channel modeling at HEC-RAS is done by inputting water level data from the results of modeling on the primary channel. The condition of the existing secondary channel DIR Belanti I is that the sluices are not used optimally (continue to be left open) so that in this study, a secondary channel is modeled by not entering the sluice data input.

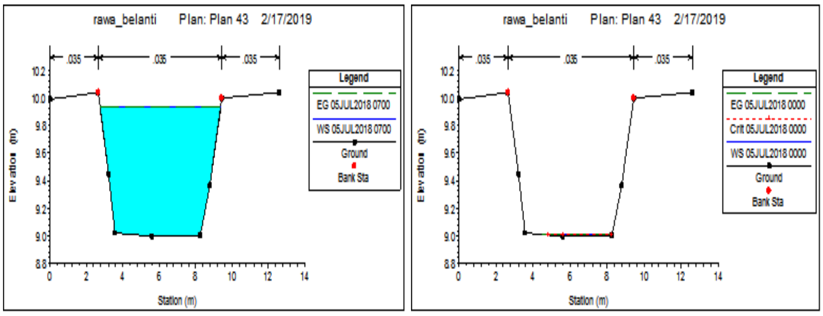
From the results of modeling on secondary channels, it can be seen that at the highest tide in the upstream area the secondary channel of water overflows out the channel so that it can cause inundation in the area around the upstream of the secondary channel. This condition does not occur every time the tide (only when the tide level is more than 2 m).

While at low tide, water from the primary channel cannot rise to the secondary channel because the water level is below the base elevation of the secondary channel. This problem occurs in all secondary channels.



(a) (b)

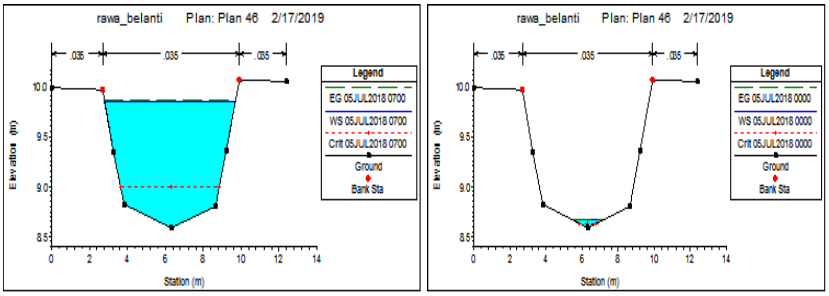
Figure 20 Upstream conditions of the left secondary channel 1 at (a) high tide and (b) low tide



(a) (b)

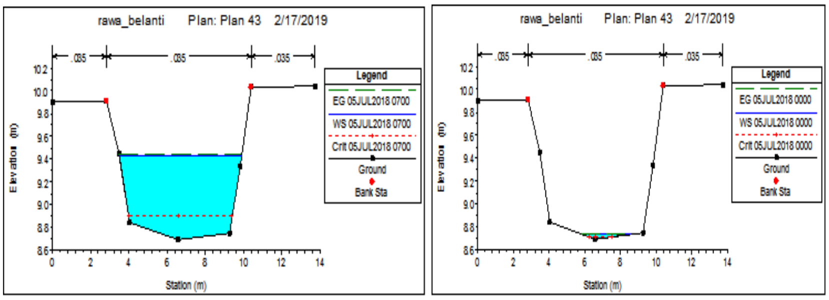
Figure 21 Upstream conditions of the right secondary channel at (a) high tide and (b) low tide

The condition of the secondary channels in the downstream of the primary canal is not found that water overflows out of the canal during the tide event. But the water level in the tide event, on average only up to half the channel height. The cross-sectional and longitudinal images of the downstream secondary channels are as follows:



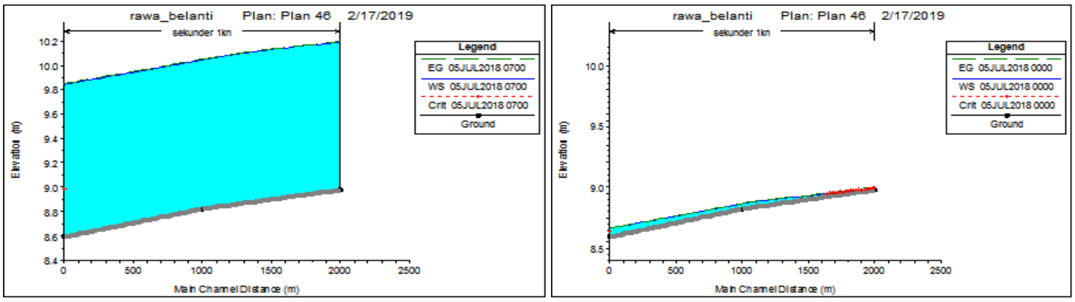
(a) (b)

Figure 22 Condition of downstream secondary channel 1 at (a) high tide and (b) low tide



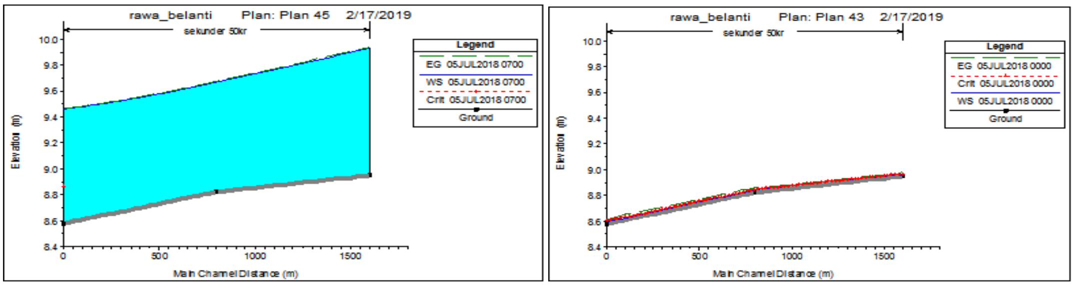
(a) (b)

Figure 23 Condition of the downstream secondary canal at (a) high tide and (b) low tide



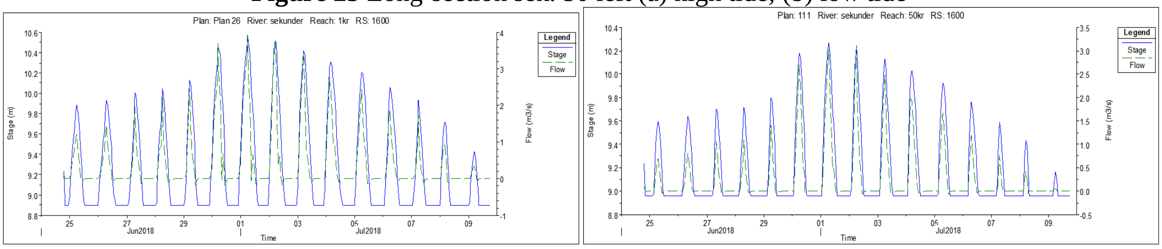
(a) (b)

Figure 24 Long-section 1 right (a) high tide; (b) low tide



(a) (b)

Figure 25 Long-section sek. 50 left (a) high tide; (b) low tide



(a) (b)

Figure 26 Graph of water level and discharge on the upstream secondary channel 1 left

- **Water Channel Evaluation and DIR Belanti I Condition**

From the results of the hydrological analysis, the amount of water demand in the DIR Belanti I for the June II period was 5.03 m^3/s and July I was 0.10 m^3/s. The 80% reliable discharge in DIR Belanti I in June was 14.79 m^3/second and in July it was 4.88 m^3/second. Whereas in the results of the primary channel modeling in the HEC-RAS period June 24, 2018, to July 9, 2018, the average discharge (upstream of the channel) was obtained at 20.946 m^3/second. From the results of the analysis, it is known that the water discharge during the simulation period can meet the water demand of DIR Belanti I.

Problems with DIR Belanti I are water level elevations in the primary canal at low tide that cannot flow to the secondary canal due to water level elevation below the base elevation of the secondary channel. So that when the conditions of receding secondary channels are not irrigated. Whereas at the time of tide, water in the secondary channels overflows outside the channel so that it can cause inundation in the area around the channel.

Overall, the supply water from the FJ Mock reliable discharge analysis on the Kahayan River is sufficient for the water demand of DIR Belanti I in June II and July I. Likewise the results of modeling with HEC-RAS show that the water level measured in that period can meet the water needs in Belanti DIR I. However, if the increase in water level during tide on the upstream primary channel is more than 2 m, it is estimated that water will run out of the canal (both primary and secondary). The highest water level is around 9.9 - 10.6 m. While the elevation of the rice fields averages at 9 m elevations, if it is not overcome it is feared that inundation can damage the rice fields and at low tide water is not available downstream of the channel.

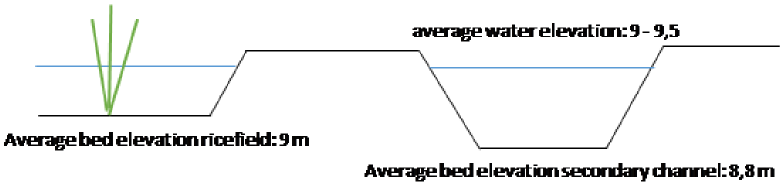


Figure 27 Sketch of ricefield elevation and secondary channel elevation.

Water balance based on the discharge from the results of the HEC-RAS modeling and water demand based on the results of the previous analysis can be seen in Figure 28.

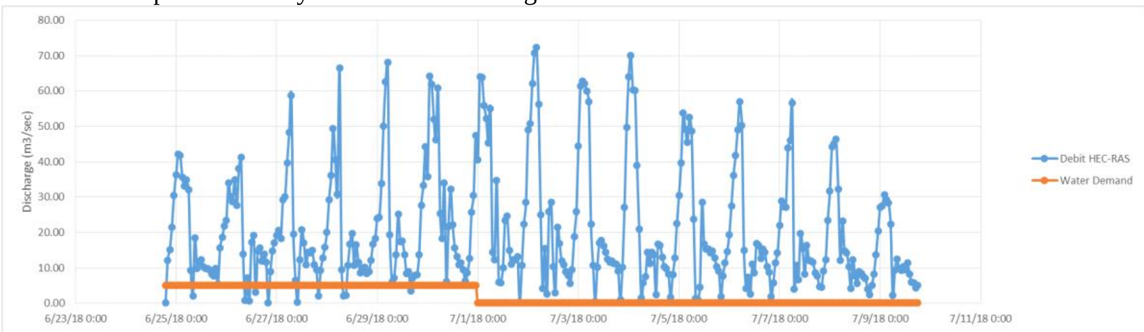


Figure 28 DIR Belanti I water balance (HEC-RAS discharge vs. water demand)

From the graph can be seen the water supply in June II and July I can meet the needs of paddy water, but only during high tide. The tide starts at 1:00 a.m. until 7:00 a.m., and begins to recede during the afternoon before 2:00 p.m.-16:00 p.m. until midnight. Tidal type in DIR Belanti I is a diurnal type or single daily tide, wherein 1 day there is one-time tide and 1-time low tide.

Try to model the sluice gate on HEC-RAS in the secondary channel 1 right as an example. Gate modeling on the right secondary channel 1 can be seen in Figure. The dimensions of the sluice are tested for the gate height of 0.7 m and a width of 1.5 m. On the right secondary channel 1, the channel width reaches 5 m so 2 gates are tried to be modeled. The gate openings are tried 0.5 m for when the water starts to plug and only opens 0.1 m at low tide. The modeling results using gates with the above scenario can reduce the water level of 6-7 cm and reduce the discharge up to 0.16 m^3/sec and the water continues to flow downstream of the secondary channel. For further development, more efficient sluice can be modeled both in terms of openings and types of gates, in order to reduce flood risk and irrigated conditions in the downstream of secondary channels. In addition, it is also necessary to model the embankment on the banks of the secondary and primary channels because if only by using the gate the possibility of flooding will still occur.

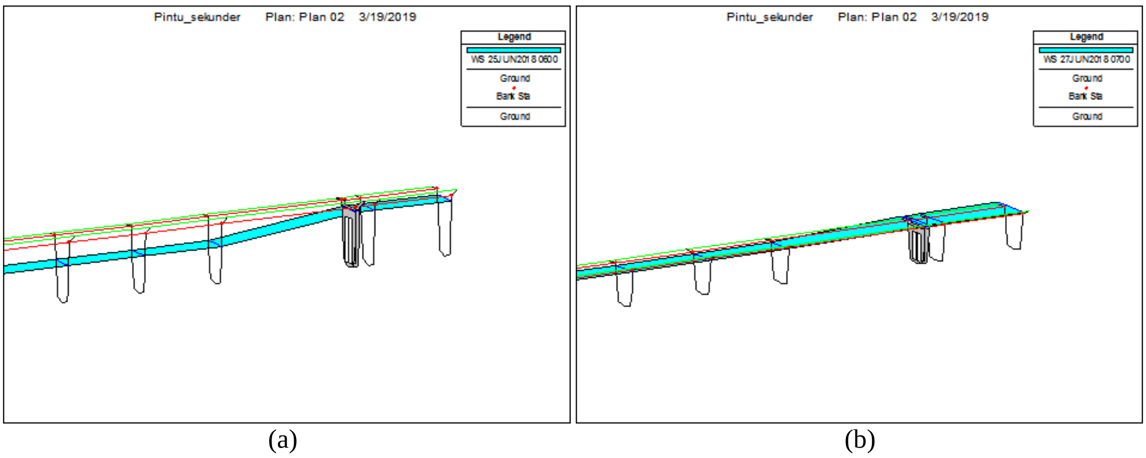


Figure 29 Secondary 1 right with the sluice at high tide in different time (a) 25 June 2019; (b) 27 June 2019

IV. CONCLUSION

The conclusions obtained from this study are:

- The water level in the primary channel at the lowest tide cannot rise to the secondary channel because the water level elevation at the primary channel at low tide is below the base elevation of the secondary channel. At high tide, water in the secondary channels overflows out of the canal so that it can cause inundation in the area around the canal. Solutions that can be done are optimizing sluice gates and making dikes and maintaining the basic dimensions and elevation of the channel.
- From the results of modeling on the upstream primary channel, the average discharge is 20.9 m^3/sec and the highest water level is +10.6 m. While the results of modeling on the primary channel downstream obtained an average discharge of 8.9 m^3/sec and the highest water level +10.2 m. The highest water level elevation on the secondary channel ranges from 9.9 - 10.6 m, while the average elevation of the paddy field is at 9 m elevations, from this it is feared that flooding can occur in the upstream secondary channel.
- Discharge in the primary channel DIR Belanti I in the simulation period is sufficient for the water demand of each secondary channel. However, at low tide, water is not available up to the secondary canal and at the time of the tide, there may be a flood. The modeling results using the sluice gate can reduce flood discharge up to 0.16 m^3/sec and reduce the 6-7 cm water level in secondary channels in the upstream area of the primary channel.

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