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Water Management in The Primary Channel of Kumpeh Swamp Irrigation Area

Narto Kurniawan[1)], Dinar DA Putranto[2*)], Sarino[2]

Abstract— The development of swamps for agricultural activities, is one of the efforts to maintain rice self-sufficiency in Indonesia, Kumpeh swamps Irrigation Area in Jambi Province, is, one of the swamps developed for agricultural activities with a potential of around 1,033.6 Ha. The Kumpeh swampy agricultural land development system, uses two primary channels to channel irrigation water or discharge excess water. The main problem in the primary channel of the Kumpeh swamps Irrigation Area is during the rainy season, there is excess water, due to the inclusion of water discharge from the Batanghari River, resulting in inundation between 50 cm to 100 cm, even at some point of the road that is the access of residents to get to the land waterlogged agriculture and plantations. The purpose of this study is to analysis how much excess water is and how to develop drainage management in the Kumpeh swamp irrigation area primary cannal, so that flood events do not occur again. The results of the analysis of average annual rainfall data were obtained at 205.5 mm. Based on the results of the measurement of discharge, obtained the average amount of discharge when it rains, amounting to 39.07 m^3/s. With a wet cross section area of the channel covering an area of 29.66 m2, the flood height of 1.44 m. With the height of the embankment from the bottom of the canal was only 1.40 m, the water overflowed and inundated the surrounding area, which caused crop failure. The condition is exacerbated by the overflow of the Batanghari river, and entering through the primary channel or the Kumpeh river, which is the main source of irrigation water. From the analysis results, for handling so that water does not always run off, it is necessary to rehabilitate the width of the channel, in the primary channel from upstream of the intake to downstream (Outlet) secondary channel, from 6 m to 6,5 m, and height the embankment was raised to 1.75 m from the initial height of 1.40 m, as well as the installation of floodgates.

Key words : *discharge, inundation, embankments*.

1 Introduction

THE development of swamp land for agricultural activities in Jambi province, is one of the efforts of the regional and Indonesian governments in maintaining food self-sufficiency. The problem with the development of irrigation areas on swamps, is to balance water needs with restrictions on excess water, when there are tidal rivers, as well as inundation from the high rainfall that exists in the area. The Kumpeh swamp irrigation area, in Jambi Province, is one of the irrigation areas that experiences high inundation problems in its primary channel, in channelling and limiting excess water during rainfall and high tides. At present the cropping pattern in the Kumpeh swamp area is rice – secondary crops planted, where the cropping pattern is carried out during the Planting of Period II (March - June) and Planting of Period III (August - November). While the planting of period I (December - February), the land could not be planted because the surface conditions were flooded between 50 cm to 100 cm. The high water level is caused by several factors including: (1) The high water level in the Kumpeh river and Batanghari river which is the inlet of the Kumpeh swamp so that it affects the existing primary and secondary channels (2) At some points of the inlet there are no floodgates, so the overflow of water from the Batanghari river entering the primary channel cannot be controlled.

One way to reduce excess water in swamp irrigation areas affected by tides is to create a good drainage system by developing drainage management to deal with excess water in the Kumpeh swamp irrigation area. This study aims to analysis the magnitude of potential discharge mainstays of the Kumpeh swamp irrigation area, analysis the influence of the Kumpeh river tides on water availability as a source of Kumpeh swamp irrigation and analysis the effect of tides on flood inundation in the primary channel. The specific purpose of this study is to analysis how much excess water is and to control drainage management in the primary canal of the Kumpeh swamp irrigation area.

2 Research Methodology

2.1 Research area

The Kumpeh swamp irrigation area is administratively located in Kumpeh District and upper Kumpeh, Muaro Jambi Regency, Jambi Province which is geographically located at the south latitute 1°24′28″ – 1°34′3″ and east longitude 103°46′10″ – 103°57′4″. The Kumpeh swamp irrigation area is at an altitude of 1 - 4 msl, with an average air temperature of 26.8°C, and 85.8% humidity and an average rainfall of 216.6 mm [1].

2.2 Research method

To analysis the causes and resolution of excess problems and reduce the height of inundation in the primary channel, an analysis which includes, forecast rain plans, calculation of flood peak discharge, measurement of channel discharge in the field and tidal observations and analysis of water needs for irrigation with various approaches as follows,

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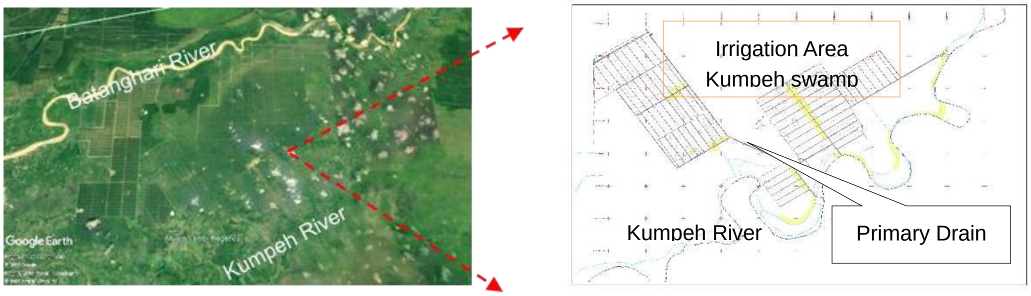

Fig. 1 Location of Kumpeh swamp irrigation area

a. Rain plan

The rain calculation plan is done by several distribution methods, namely the Normal Method, Normal Log, Gumbel, and Pearson Type III log. Chi-Square Test was performed to test the suitability of the distribution for the four equations using Chi Square (X^2) [2] :

$$X^2_{count} = \sum_{i=1}^{k} \frac{(Fe - Ft)^2}{Ft} \quad ....(1)$$

Where,

X^2_{count} : *Chi-Square* count it ;
Fe : Frequency of class observations j;
Ft : Theoretical frequency class j;
K : Number of classes.

b. Rain intensity

Rain intensity was analyzed using the Mononobe method[3]:

$$I = R_{24} / 24[24/t]^n \quad ....(2)$$

With
I : rainfall intensity (mm/hours);
t : time concentration of rainfall (hours), for Indonesia 5~7 hours;
R_{24} : maximum of rainfall per day (mm/hours),
n : constant (estimate for Indonesia n~2/3).
Note: the reset factor factor is entered in R_{24}.

c. Calculation of flood peak discharge using the equation HSS Nakayasu[4],

$$Qp = \frac{c.A.R_O}{3,6(0,3Tp + T_{0,3})} \quad .... (3)$$

With
Qp : Qmaks, is the peak flood discharge (m^3/sec);
c : flow coefficient (= 1);
A : watershed area (until to *outlet*) (km^2);
Ro : unit rain (mm);
Tp : time period from the time it rains to the peak of the flood (hours);

d. Irrigation water need estimated irrigation water needs are based on the Department of Public Works regulations, [5]

(1) the need for clean water in rice fields for rice

NFR = Etc + P – Re + WL................ ….. (4)

(2) irrigation water need for rice, WRD

IR = NFR/e... (5)

(3) land preparation needs for rice

(4) Irrigation water needs for secondary crops, WRP

IR = (Etc – Re)/e..................................... (6)

Where,
Etc : consumptive use;
P : water loss due for percolation (mm/days);
Re :Effective rain fall (mm/days);
E : efficiency of irrigation for all ;
WLR : water replacement (mm/days)

e. Tidal

Tidal data (water level fluctuations) are obtained by observing in the field on SK 4 Channel Right Block F, where the channel also functions as a drainage channel. Tidal observations (water level fluctuations) were carried out for 14 days using *Peilschaal*.

f. Hydraulics Analysis

The use of HEC-RAS software for channel modeling analysis is based on channel geometry and inflow data in the form of flood discharge obtained by direct measurements in the field and water level fluctuations data. The channel modeling output is in the form of a flood water level for each fluctuation in water level. From this data the flood control scenario is then carried out, by adding the height of the embankment, widening the base of the channel and adding floodgates.

3. Results and Discussion

The initial data source that can be used as a guideline to support this research is rainfall distribution data or river water discharge data.

3.1 Plan Rain Analysis

The repeat period is a hypothetical time in which an event with a certain value will be equaled or exceeded once in the hypothetical period. The return periods are calculated for each method, namely the 2, 5, 10, 25, 50 and 100 year return periods using rainfall data from 2009 to 2018 at the Suak Kandis rain station post, Jambi Province.

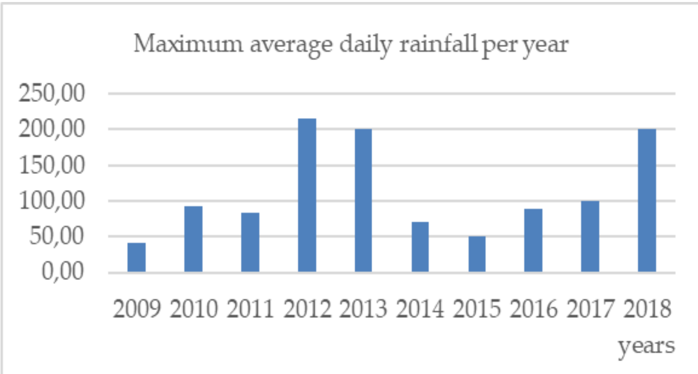

Fig. 2 Maximum Daily Rainfall

Figure 2 above provides information that the highest maximum daily rainfall data occurred in 2012 of 215 mm and the lowest occurred in 2009 of 48 mm.

Table 1 Distribution test results can be seen that the distribution that meets the criteria is the Pearson Type III Log distribution and Gumbel distribution.

TABLE 1
Results of Calculated Rainfall Plans

	Distribution Type of Rainfall frequency (mm)			
T (Year)	Normal	Normal Log	Person III Normal Log	Gumbel
2	114.20	98.53	97.15	105.32
5	169.32	159.83	159.06	183.50
10	198.14	205.81	207.56	235.26
25	221.94	253.61	264.26	284.91
50	248.72	320.80	335.45	349.18
100	266.57	375.21	399.13	397.34

The rainfall plan (R) in the table above can be displayed in the graph below,

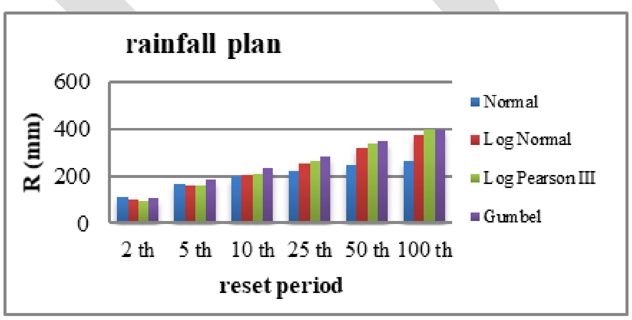

Fig. 3 Rainfall frequency distribution

3.2 Chi Square test

Chi Square test results of Pearson Type III Log distribution and Gumbel distribution obtained the Chi-Critical Square (X^2cr) parameter = 6.635 for degrees of freedom (df) = 3 and confidence level (α) = 5% so that the Chi Square value is calculated (X^2 count) = 0.159 . Because the X^2 count is smaller than X^2cr, it means that the data corresponds to both distributions. Because the Variance Coefficient (VC) of the Pearson Type III Log distribution is smaller than the Gumbel distribution, the Pearson Type III Log distribution is used.

3.3 Mainstay rainfall

The rainfall distribution method used by the distribution test results is the Log Pearson III method. The result is obtained a reliable rainfall of 80% (R_{80}) 183.65 mm. Thus it can be concluded that the 80% reliability opportunity occurs at a probability of 30%, ie between 180 mm and 191.9 mm of rainfall.

3.4 Rainfall Intensity

The intensity of rainfall (I) and maximum daily rainfall (R_{24}) of the calculation results can be explained in the figure 4.

TABLE 2
Results of Calculated Rainfall Intensity for reset period

t (min)	t (h)	I (mm/hour) Reset period (Year)				
		2	5	10	20	50
5	0,08	176,53	289,02	377,16	480,20	609,56
10	0,17	111,21	182,07	237,59	302,51	384,00
15	0,25	84,87	138,95	181,32	230,86	293,04
30	0,50	53,46	87,53	114,22	145,43	184,61
45	0,75	40,80	66,80	87,17	110,98	140,88
60	1,00	33,68	55,14	71,96	91,62	116,29
120	2,00	21,22	34,74	45,33	57,71	73,26
180	3,00	16,19	26,51	34,59	44,04	55,91
240	4,00	13,37	21,88	28,56	36,36	46,15
300	5,00	11,52	18,86	24,61	31,33	39,77
360	6,00	10,20	16,70	21,79	27,75	35,22
720	12,0	6,43	10,52	13,73	17,48	22,19

The data in Figure 4, above states that for a return period of 2 years the maximum daily rainfall (R_{24}) is 176.53 mm and for a 50 year return period is 609,56 mm.

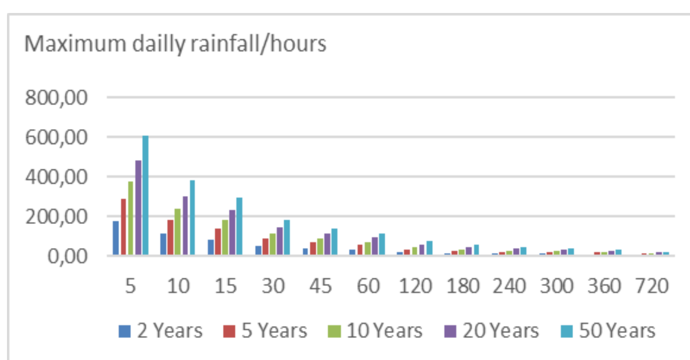

Fig. 4 Maximum daily rainfall/hours

3.5 Mainstay Discharge

The results of rainfall data analysis using the probability method is known that rainfall data and the number of rainy days (rd) that can be used is the rainfall data for 2016. From the calculation results obtained by the reliable discharge as follows,

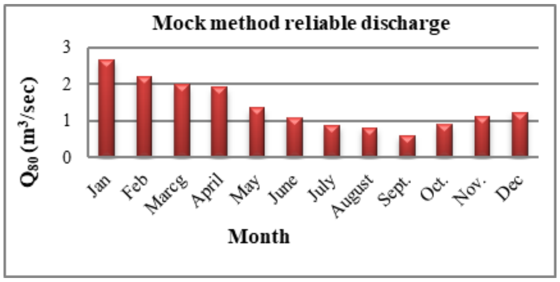

Fig. 5 Mainstay discharge Mock method

The magnitude of the mainstay discharge stated in Figure 5 above is the highest mainstay discharge occurred in January, which is 2.67 m^3/s and the lowest occurred in September of 0.61 m^3/s. This means that the decline in reliability occurs from January to September.

3.6 Nakayasu Synthetic Hydrograph Unit

The results of the calculation of the Nakayasu Synthetic Hydrograph can be obtained the magnitude of flood discharge for a return period of 2 years to 100 years, namely

TABLE 3
Nakayasu method flood peak discharge

Reset time T (year)	peak flood discharge (Q_p) (m^3/sec)
2	277,239
5	487,489
10	587,290
20	746,236
25	835,200
50	958,759
100	1125,500

The Nakayasu method flood discharge above can be outlined in the form of a hydrograph model shown in the following graph,

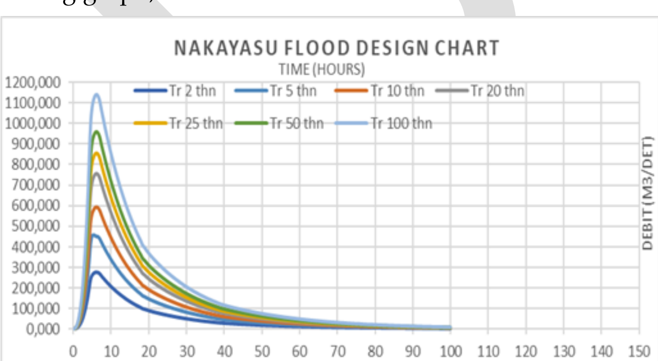

Fig. 6 Nakayasu Synthetic Hydrograph Swamp Kumpeh irrigation area

3.7 Network hydraulics analysis

The Kumpeh swamp network system has 3 inlet (inlet water flow) and 1 outlet (outflow water). The inlet is from Batanghari river (1 inlet) and Kumpeh river (2 inlet). The inlet originating from the Batanghari river is in the primary channel Block B while the inlet originating from the Kumpeh river is in the primary channel Block E and the primary channel Block F (Section 1). The outlet is in the secondary channel SK 4 Right Block F. The flow diagram of the Kumpeh swamp network can be seen in Figure 7, while the amount of inlet and outflow can be seen in table 4.

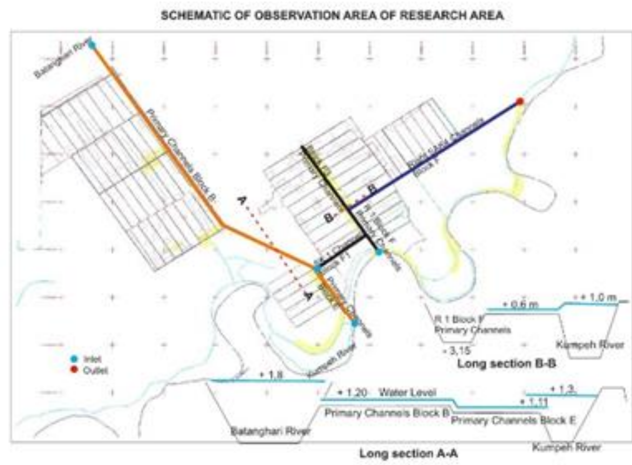

Fig. 7. Scematic of observation area of research area

From the results of observing the flow velocity using the Current Meter at the study site, the flow velocity (v) on the Block B Primary Channel obtained a value of 0.47 m/s. The water level (h) from the bottom of the channel is 2.40 m. From the cross-sectional data and the measurement of water surface depth, the wet cross-sectional area (A) is worth 16.36 m^2, so that the discharge (Q) = 0.47 m/s. 16.36 m^2 = 7.68 m^3/sec. The calculation results are then used to carry out an analysis using HEC-RAS.

TABLE 4
Analysis of the discharge of measurement results

No	Channel name	speed (meter/seconds)	Wet cross sectional area (m^2)	Debit (m^3/sec.)
1	Primary Block B	0.47	16.36	7.68
2	Primary Block E	0.63	28.13	17.63
3	Left Secondary (SK 1 Block F)	0.73	15.72	11.44
4	Primary Block F (Segment 1)	0.35	57.92	20.00
5	Primary Block F (Segment 2)	0.73	39.45	28.75
6	Primary Block F (Segment 3)	1.32	29.66	39.07
7	Right SK 4 Block F	0.38	17.83	6.75

From the results of the discharge measurements shown in table 4, the largest discharge occurred in the primary F block (Segment 3) of 39.07 m^3/sec, while the smallest discharge occurred in the SK 4 block F secondary channel where the channel also functions as a dump in the Kumpeh swamp area.

3.8 River Water Discharge Based on Comparison of Rainfall Occurred

River water discharge (Q) when rainfall is low in October 2018 results of measurements of river flow velocity using Current meters and river cross section using Echosounder is 31.80 m3/sec. River water discharge (Q) during moderate rainfall of 219.97 m^3/sec is obtained based on the ratio of river water discharge and rainfall that occurs when rainfall is low in October with moderate rainfall in November. The results of comparison of river water discharge and low rainfall in October with prediction of high rainfall in January obtained river water discharge (Q) during high rainfall of 426.35 m^3/sec.

3.9 Water level based on water level fluctuations

Tide analysis (water level fluctuations) is used in determining the boundary conditions on the SK 4 channel Right Block F which is a drain in the Kumpeh swamp network system. The tidal graph on the right channel SK 4 Block F can be seen in figure 9. Fluctuations that occur are tides of mixed single dominant (mixed-dominant diurnal) to $0.50 < F \leq 3.00$.

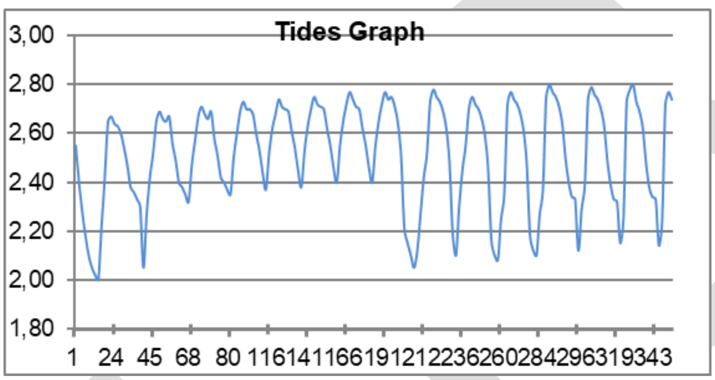

Fig. 9 Data of Kumpeh River Fluctuations in Height for 14 Observation Days

3.10 River Water Discharge Based on Prediction of High Fluctuations in Water

River water discharge is obtained from the multiplication between the total river cross-sectional area (A) and the river flow velocity (V). The measurement results using Echosounder and Current Meter and water level from river water level fluctuation data can be seen that :

(1) Based on average height of low water level over a period of 19 years (MLWL) 2.08 m, obtained river water discharge (Q) when rainfall is low at 34.37 m3 / sec;

(2) Based on the average height of the high water level over a period of 19 years (MHWL) 2,48 m the river water flow obtained during moderate rainfall amounted to 244.7 m^3/sec;

(3) Based on the highest water level at the time of the tidal full moon (HHWL) 2,8 m, river water discharge obtained during high rainfall was 426.35 m^3/sec;

3.11 Prediction of Availability of Average River Water Discharge per Month Based on Fluctuations in Surface Water and Rainfall Occurred

The average river water discharge (Qrt) per month can be displayed on the following graph,

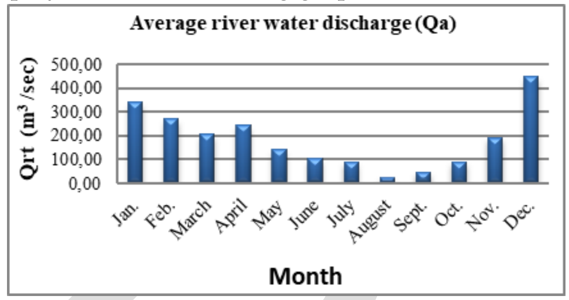

Fig. 10 Monthly River Water Discharge (Qrt)

The highest average river water flow (Qrt) based on Figure 10 above occurred in December, which was 446.60 m^3/s and the lowest occurred in August 34.36 m^3/s. The predicted results of the average water level (AWL) per month can be displayed in the following table 5

TABLE 5
Water Discharge prediction in the Kumpeh swamp Area per month

Month	Water discharge (m3/sec)
Jan.	2,6
Feb.	1,84
March.	2,23
April	2,65
May	1,53
June	1,11
July	0,98
August	0,16
Sept.	0,2
Oct.	0,34
Nov.	1,11
Dec.	2,67

3.12 Excess Water in the Kumpeh Swamp Area and Adjustment of the Normalization Plan of the primary cannal

The plan to prepare land in the Kumpeh swamp area for planting rice 1st is strongly influenced by excess water in the area because it is not possible to plant if the amount of water is too excessive. The excess water for the 1st planting season in the Kumpeh swamp areas above based on the analysis of water availability can be explained as follows,

The excess water in the primary canal based on the results of the analysis was 1,866 m^3/sec (161,222.4 m^3/day). The highest prediction of swamp water according to Table 5 occurred in December at 2.67 m^3/sec (192,326.4 m^3/day) and the lowest in August was 0.16 m^3/sec (41,731.2 m^3/day). To reduce the height of water in the SK 4 right secondary channel, it is necessary to engineer the channel.

The canal engineering plan that can be applied to the swampy Kumpeh area, based on the water discharge above,

(1) Expanding the channel bottom from 6 m to 6.5 m, and raising the embankment from 1.4 m to 1.75 m, is expected to reduce the water level in the secondary channel F4 to 0.4 m, so that it is expected that the water will not flooding;

(2) Planting pattern plan for the 1st planting season is planted with rice (alabio, tapus, and hiyang rice) because the existing water discharge is still quite high secondary crops at the end of June - September.

4 CONCLUSIONS

(1) The magnitude of the effect of river water discharge is able to support the availability of water for irrigation activities based on the planned Rice - Rice – secondary crops pattern with the 1st rice planting period (end of November - March) taking place during high rainfall, river water discharge (30%) which can be used for irrigation of 62.877 m3 / sec;

(2) Excess water due to high rainfall and inadequate canal capacity is overcome by increasing channel width and embankment height, to increase storage capacity, and regulating it by making floodgates on primary channel Block F3 to right secondary channel SK F4

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