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Model Hydrology MockWyn-UB to Analyse Water Availability in Gumbasa Watershed Central Sulawesi Province

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ABSTRACT
From the results of previous studies stating that the watershed Gumbasa there has been a change in climate, discharge models used in calculating the availability of water in a watershed used the model MockWyn-UB Studies conducted Gumbasa watershed has an area of 1229.43 km^2 with AWLR outlet Gumbasa River. Based on the analysis, the relationship between the discharge of models and the discharge observation forming a uniform pattern except in 2013 which discharge higher models of discharge observation. The correlation coefficient between the discharge and the discharge observation models do not qualify so the calibration data using the facility solver is not done. Thus the calibration is done using the Root Mean Square Error (RMSE). RMSE value MockWyn-UB acquired 3.10%. While the results of the analysis models Mock RMSE values obtained 8.03 %.Comparison between the using of model FJ. Mock and model MockWyn-UB with using test parameters RMSE statistics showed an error rate MockWyn-UB models better than models FJ. Mock. Model MockWyn-UB do not optimal if applied in the watershed Gumbasa, this is caused by the presence of Lake of Lindu are located in the basin Gumbasa.

Keywords: FJ. Mock, Gumbasa Watershed, Lake Lindu, MockWyn UB, RMSE.

I. INTRUDUCTION

The condition of the rainy season and the dry season in the last few years is no longer in accordance with the conditions that existed before. This is influenced by the existence of global warming due to greenhouse effect so that the air temperature of the earth has increased significantly, this phenomenon is called climate change.With the climate change, will affect the hydrological processes that occur in the watershed. Gumbasa watershed is part of the Palu watershed area of 1229.43 km^2 has tipped in Masomba mountain, Mount Nokilalaki and Lake of Lindu. With a large area Watershed Gumbasa also do not immune from climate change. Given that climate change will certainly affect the availability of water and hydrologic conditions that occurred in the river basin. When this has been a lot of modeling discharges that have been found by Hydrologists including model of FJ. Mock 1973[1], NRECA Model[2],Model Nugroho[3], Model MockWyn-UB [4] of the many modeling discharge mentioned above, only one model that incorporate climate change parameters in calculating the availability of water in a river basin. That is the model MockWyn-UB. This discharge models by Sutapa, I.Wayan [4] is a model of the balance of water / rain water flow balance climate simulations based on development of the model FJ. Mock [1] by the model name MockWyn-UB. This research was carried out by inserting a natural phenomenon that occurs at this time these as a novelty in this study such as climate change, canopy interception, rainfall distribution based on land use, soil type and soil characteristics. Model Mockwyn-UB a new debit calculation d.To prove the reliability it needs to be applied in other watersheds, which has wide and different characteristics of the watershed Previous.

II. RESEARCH METHODS

The location this research lies in the watershed of Gumbasa is part of the watershed area of Palu have 1229,43 km^2 at Masomba mount, Nokilalaki mount dan Lake Lindu. Geographically situated the River watershed Gumbasa between 01^0 01' LS – 01^0 21'LS and 119^{0}56' BT – 120^{0}19' BT. The location study can be seen in the map below:

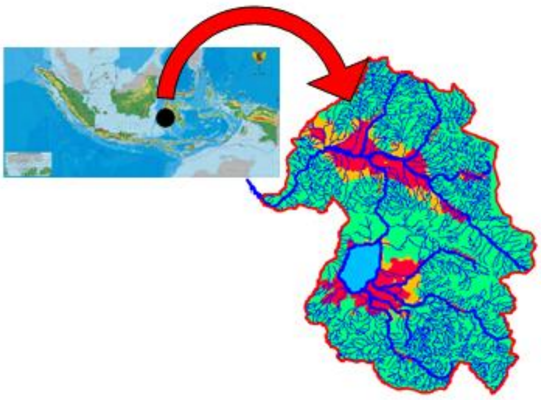

Figure 1. Location of research

The type of data used in this study consisted of primary data and secondary data. The primary data in the form of soil samples doing in Kapiroe Village, Village Tongoa and Sintuwu, Secondary data consists of: 1) the data of precipitation at the station Bora, Bangga Low, Kulawi, Palolo, Wuasa (2002-2015); 2) data of climatology at stations Bora (2002-2015); 3) data of discharge Gumbasa river; 4) map of the earth Indonesia; 5) map of land use (2015). Data collection techniques in this research refers to research that has been done by I Wayan Sutapa (2013).

The data used as input in the modeling of the discharge was analyzed in the following methods:

a. Detection of the presence or absence of climate trends and make projections of climate change. In this study the above step, not done because previous research has shown that in the region there has been a climate change.

b. Analysis of average rainfall watershed using methods Theissen [5,6] caused rainfall data is not uniform, the calculate of rain continued net based with land cover using an research dunne and Leopold [7]

c. Calculate potential evapotranspiration with using the Penman Monteith [8]

d. The calculated water balanced with use model of MockWyn UB[4]

e. Result calibration model the discharge of MockWyn UB with data AWLR at Gumbasa river, the using of method of statistic *Root Mean Square Error*[9]

The tank model of MockWyn UB can be seen in Figure 2.

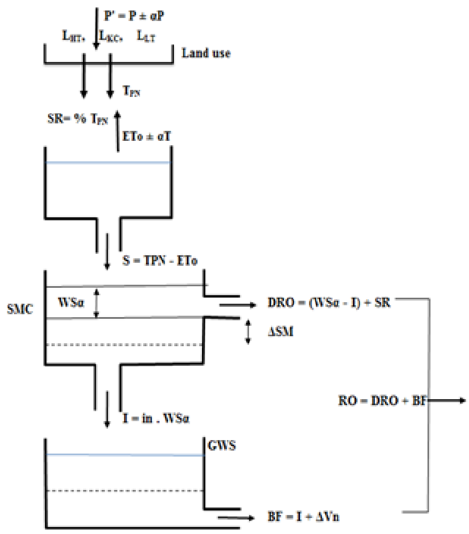

Figure 2. Tank model of MockWyn UB[1]

III. RESULT AND DISCUSSION

3.1 Deposits of groundwater

The primary data in the form of soil samples and vegetation based on the existing land is: open land, gardens and forests mix. Soil sampling was conducted on March 27, 2016 in the village Kapiroe, villages Tongoa and Sintuwu. Soil samples are then analyzed in Soil Mechanics Laboratory University of Tadulako to determine the soil moisture content at each layer of soil. Groundwater levels are described in Table 1

Table 1. Water content of soil

No	Location of Sample	Subsoil	Thick (mm)	Water content (%)	Content weight of soil (gr/cm³)	Water content volumetric (%)	Thick of water content (mm)
1	TP 01 (garden) Village of Sintuwu	Layer of surface	150	23.26	1151	26.77	40.16
		Layer of root	650	20.59	1440	29.65	192.72
		Layer of moist	500	9.23	1514	13.97	69.87
						Average	**199.92**
2	TP 02 (Forest) Village of Tongoa	Layer of surface	150	16.20	1250	20.25	30.37
		Layer of root	650	9.85	1544	15.21	98.85
		Layer of moist	500	8.95	1682	15.05	75.27
						Average	**68.16**
3	TP 03 (Land open) Village of Kapiroe	Layer of surface	150	25.37	1721	43.66	43.66
		Layer of root	650	22.34	1672	37.35	186.76
		Layer of moist	1000	25.78	1779	45.86	458.62
						Average	229.68
						Average	**132.92**

The results of analysis initial deposit groundwater is 45.56 mm, while the maximum water savings is calculated using the method of De Laat[10]be obtained 186.67 mm.

3.2 Average rainfall

The method used to calculate the average rainfall is a method of Thiessen[5,6], this method is used if the spread of rainfall stations in areas of interest uneven. Data from the average rainfall can be seen in the table 2

Table 2. Average of Precipitation

No	Month	Average Rainfall Data Year 2002 (Station)					Precipitation Method of Thiessen (Station)					Precipitation
		Bora	Kulawi	Palolo	Bangga B	Wuasa	Bora	Kulawi	Palolo	Bangga B	Wuasa	Region (mm)
1	January	110.00	133.10	9.80	90.60	106.00	7513.00	42005.029	1750.28	25343.54	22473.06	93.99
2	February	9.70	34.30	0.00	24.90	75.60	662.51	10824.737	0	6965.277	16027.96	32.71
3	March	44.10	336.30	71.90	3.40	243.80	3012.03	106132.92	12841.34	951.082	51688.04	165.64
4	April	0.00	435.20	211.30	0.00	125.30	0.00	137344.77	37738.18	0	26564.85	191.27
5	May	145.60	193.00	84.30	42.00	124.90	9944.48	60908.87	15055.98	11748.66	26480.05	117.75
6	June	127.00	128.10	100.30	259.50	155.90	8674.10	40427.079	17913.58	72589.94	33052.36	163.78
7	July	135.00	102.00	74.90	107.20	23.70	9220.50	32190.18	13377.14	29987.06	5024.637	85.18
8	August	20.00	61.20	119.50	36.70	55.40	1366.00	19314.108	21342.7	10266.09	11745.35	60.74
9	September	0.00	121.20	52.60	121.80	196.20	0.00	38249.508	9394.36	34071.11	41596.36	116.97
10	October	5.00	89.40	5.90	83.40	24.50	341.50	28213.746	1053.74	23329.48	5194.245	55.14
11	November	0.00	195.60	23.00	184.30	109.40	0.00	61729.404	4107.8	51554.24	23193.89	133.35
12	December	126.80	181.70	48.20	55.30	198.80	8660.44	57342.703	8608.52	15469.07	42147.59	125.43

3.3 Potential evapotranspiration

Potential evapotranspiration calculated by Penman Monteith method [8] is based on climatology data Bora station for observation period 2002-2015.

Tabel 3. Evapotranspiration of potential

Year	January	February	March	April	May	June	July	August	September	October	November	December
2002	105.41	90.70	101.96	115.78	108.19	80.81	124.85	129.91	112.76	126.85	113.66	119.41
2003	99.35	87.73	95.43	100.33	111.68	115.83	94.30	92.64	97.04	38.38	110.83	47.30
2004	107.29	90.23	107.84	103.57	110.88	102.95	98.29	126.79	116.43	131.74	118.90	117.39
2005	106.28	96.57	130.84	104.59	106.91	101.99	100.42	127.74	102.38	118.24	96.49	84.18
2006	98.27	99.79	110.63	103.58	119.81	93.31	115.28	121.17	114.74	124.63	111.81	108.22
2007	91.54	102.40	99.71	99.89	110.58	60.37	74.70	84.76	105.91	92.09	24.40	89.19

Tabel 3. Evapotranspiration of potential (Continued)

Year	January	February	March	April	May	June	July	August	September	October	November	December
2008	101.05	80.76	91.53	89.93	64.28	33.50	35.48	37.40	39.39	42.36	39.77	40.65
2009	96.60	71.81	103.33	106.59	104.49	82.46	110.32	121.43	39.39	42.36	39.77	40.65
2010	99.82	110.53	119.58	91.27	108.25	100.74	93.49	94.02	119.08	113.09	117.15	64.65
2011	100.57	72.37	86.94	90.04	107.52	97.75	88.86	113.75	103.45	125.05	108.48	91.57
2012	97.43	73.29	116.16	122.95	134.12	101.58	108.35	138.61	143.82	139.37	124.57	119.85
2013	110.72	112.22	134.38	113.70	113.57	105.76	80.05	110.57	127.01	135.50	121.03	114.47
2014	80.95	158.74	135.33	126.34	113.38	99.03	133.53	124.55	145.53	156.62	120.12	41.70
2015	95.45	98.53	107.65	102.27	109.65	86.46	120.67	134.23	128.59	36.63	114.69	104.97

3.4 Discharge of MockWyn UB

Calculation of net rainfall is the average monthly precipitation fell in each land located in the watershed of Gumbasa.

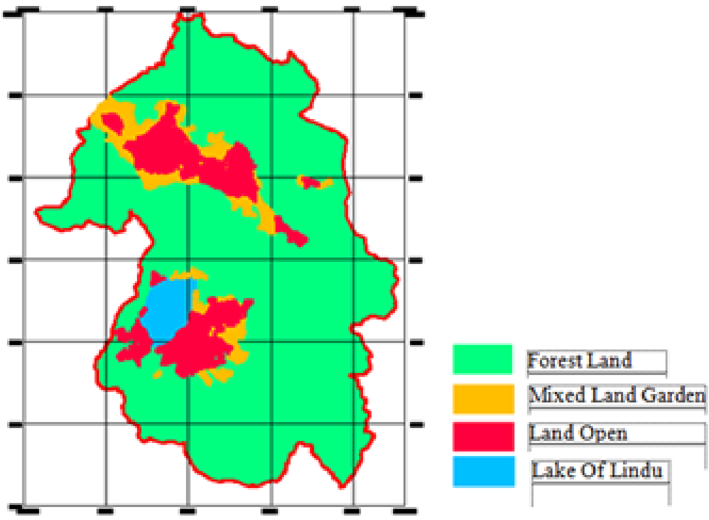

Figure 3. Land use

Table 4. Area of Land Use

No	Land Use	Unit	Area
1	Forest land	Km^2	955.85
2	Mixed land Gardens	Km^2	113.28
3	Land Open	Km^2	103.91
4	River and Lake	Km^2	56.39
Amount			**1229.43**

The results of analysis of net rainfall Gumbasa for watershed areas, so that the flow rate calculation MockWyn-UB[1] can be done. The simulation model MockWyn UB models can be seen in Table 5

Table 5 . Simulation of discharge model MockWyn UB in Year 2002

No.	Explanation	Unit	Exp	Jan	Peb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Des	Year
I	**VEGETATION**															
1	Forest land (LHT)	km^2	955.85	DATA												
2	Mixed Land gadens (LKC)	km^3	113.28													
3	Land open (LLT)	km^4	103.91													
4	Area of Watershed (LDAS)	km^5	1229.43													
II	**Rain & EVAPOTRANSPIRATION**															
5	The average monthly rainfall (P)	mm/mth	data	93.99	32.71	165.64	191.27	117.75	163.78	85.18	60.74	116.97	55.14	133.35	125.43	1341.95
	The average monthly rainfall (P)... Corrected αP	mm/mth	1.200	112.79	39.25	198.77	229.53	141.30	196.53	102.22	72.89	140.36	66.17	160.02	150.51	1610.34
6	Rain in the Forest (PHT)	mm/mth	count	87.69	30.51	154.54	178.45	109.86	152.80	79.47	56.67	109.13	51.45	124.41	117.02	1252.00
7	Rain in the gardes mixed (PKC)	mm/mth	count	10.39	3.62	18.31	21.15	13.02	18.11	9.42	6.72	12.93	6.10	14.74	13.87	148.38
8	Rain in the open land (PLT)	mm/mth	count	9.53	3.32	16.80	19.40	11.94	16.61	8.64	6.16	11.86	5.59	13.53	12.72	136.10
9	Rain net in the forest (PNHT) =0,886P + 0,088	mm/mth	count	77.78	27.12	137.01	158.20	97.42	135.47	70.50	50.30	96.78	45.67	110.32	103.77	1110.33
10	Rain net in the garden mix (PNKC)=0,925P+0,333	mm/mth	count	9.95	3.68	17.27	19.90	12.38	17.08	9.04	6.55	12.30	5.97	13.97	13.16	141.24
11	Rain net on open land (PNLT)	mm/mth	count	9.53	3.32	16.80	19.40	11.94	16.61	8.64	6.16	11.86	5.59	13.53	12.72	136.10
12	Total rainfall net (TPN)	mm/mth	count	97.26	34.12	171.08	197.49	122.74	169.16	88.18	63.00	120.93	57.28	137.82	129.65	1387.68
13	Evapotranspiration of potencial (ETo)	mm/mth	count	105.41	90.70	101.96	115.78	108.19	80.81	124.85	129.91	112.76	126.85	113.66	119.41	1330.30
14	Evapotranspirastion actual (ETA)															
	TPN > ETo then ETA = ETo	mm/mth	count	--	--	101.96	115.78	108.19	80.81	--	--	112.76	--	113.66	119.41	752.57
	TPN < ETo then ETA = TPN + ΔSM	mm/mth	count	97.26	80.84	--	--	--	--	122.47	109.22	--	115.35	--	--	524.12
III	**WATER BALANCED**															
15	The difference between TPN WITH n ETo (S = TPN - ETo)	mm/mth	(12) - (13)	-8.15	-56.58	69.12	81.72	13.55	88.35	-36.67	-66.91	8.17	-69.62	24.16	10.24	
16a	The loss of potential water	mm/mth	count	-8.15	-56.58	0.00	0.00	0.00	0.00	-36.67	-66.91	0.00	-69.62	0.00	0.00	
16b	Accumulation of potential water loss (APWL)	mm/mth	count	-8.15	-64.73	0.00	0.00	0.00	0.00	-36.67	-103.58	0.00	-69.62	0.00	0.00	
17	Soil moisture SM = SMC.e ^-(APWL / SMC)	mm/mth	count	178.70	131.97	186.67	186.67	186.67	186.67	153.38	107.17	186.67	128.56	186.67	186.67	
18	The Cgane of Soil Moisture (ΔSM)	mm/mth	count	0.00	-46.72	54.70	0.00	0.00	0.00	-33.29	-46.20	79.50	-58.11	58.11	0.00	
19	Deficit (WD = ETo - ETA)	mm/mth	(13) - (14)	8.15	9.85	--	--	--	--	3.38	20.71	--	11.51	--	--	53.60
20	Moisture of Water (WS)	mm/mth	Count	0.00	0.00	69.12	81.72	13.55	88.35	0.00	0.00	8.17	0.00	24.16	10.24	295.30
IV	**STORAGE OF SOIL & WATER RUNOFF**															
21	Factor (In) Value 0,2 - 0,5	0.500	data													
22	Factor (k) Value 0,4 s/d 0,7	0.700	data													
23	Infiltration (I = In. WS)	Mm/mth	(20) x (21)	0.00	0.00	34.56	40.86	6.77	44.18	0.00	0.00	4.09	0.00	12.08	5.12	
24	G = 0,5 (1 + k) x I	mm/mth	hitung	0.00	0.00	29.38	34.73	5.76	37.55	0.00	0.00	3.47	0.00	10.27	4.35	
25	L = k. V(n-1)	mm/mth	Count	31.89	22.32	15.63	31.50	46.36	36.48	51.82	36.28	25.39	20.72	14.14	17.09	
26	Volume penyimpanan (Vn = G + L)	mm/mth	(24) + (25)	31.89	22.32	45.00	66.23	52.12	74.03	51.82	36.28	28.87	20.72	24.41	21.44	
27	Changes saved (ΔVn = (V_{n-1} - Vn)	mm/mth	Count	13.67	9.57	-22.68	-21.28	14.11	-21.91	22.72	15.55	7.41	8.66	-4.20	2.97	24.12
28	Base Flow (BF = I + ΔVn)	mm/mth	(23) + (27)	13.67	9.57	11.88	19.63	20.89	22.26	22.72	15.55	11.50	8.66	7.87	8.09	171.77
29	Direct Runoff (DR = WS - I)	mm/mth	(20) - (23)	0.00	0.00	34.56	40.86	6.77	44.18	0.00	0.00	4.09	0.00	12.08	5.12	147.65
30	Runoff (RO = BF + DR)	mm/mth	(28) + (29)	13.67	9.57	46.44	60.49	27.66	66.44	22.72	15.55	15.58	8.66	19.95	13.21	319.42
V	**STORM RUNOFF, (SR**															
31	Areas of heavy rain (SR = %TPN)	% x TPN	0.3	29.18	10.24	0.00	0.00	0.00	0.00	26.45	18.90	0.00	17.17	0.00	0.00	101.94
32	Exess Water (WSα)		Simulation	0.00	0.00	69.12	71.48	13.55	59.17	0.00	0.00	8.17	0.00	24.16	10.24	255.89
33	Direct Runoff (DR = WSα - I) + SR	mm/mth	Caount	29.18	10.24	34.56	30.62	6.77	15.00	26.45	18.90	4.09	17.17	12.08	5.12	210.18
34	Runoff (RO = BF + DR)	mm/mth	(28) + (33)	42.85	19.80	46.44	50.25	27.66	37.26	48.66	34.45	15.58	25.83	19.95	13.21	381.95
35	Total Day			31	28	31	30	31	30	31	31	30	31	30	31	
36	Discharge of Avalaible	m^3/sec	(34) x (4) / bl	19.67	10.06	21.32	23.84	12.70	17.67	22.34	15.81	7.39	11.86	9.46	6.06	178.18
36a	Factor of Discharge correction (β)	**1.000**		19.67	10.06	21.32	23.84	12.70	17.67	22.34	15.81	7.39	11.86	9.46	6.06	178.18
37	Initial Deposit (V_{n-1}) =	mm	**45.56**													
38	SMC =	mm	**186.670**	The maximum soil moisture capacity												

The accuracy of the results of a model needed to test whether the model used to calculate a study can be used in other places with different parameters. The research results are presented in Table 6

Table 6. Comparison between discharges of model with discharge of observation

No	Year	Discharge of Model (met^3/sec)	Discharge of Observation (met^3/sec)	Percentage Storage	P=100m/(n+1)	Ranking	
						Discharge of Model	Discharge of Observation
1	2002	14.85	20.79	28.58%	0.07	39.32	56.07
2	2003	26.15	28.75	9.05%	0.14	33.31	42.19
3	2004	13.50	23.00	41.32%	0.21	32.09	34.17
4	2005	16.06	33.50	52.07%	0.29	26.15	33.50
5	2006	14.68	23.96	38.72%	0.36	19.82	30.97
6	2007	33.31	42.19	21.04%	0.43	18.75	28.75
7	2008	39.32	56.07	29.87%	0.50	16.06	28.74
8	2009	11.19	23.14	51.64%	0.57	14.86	26.98
9	2010	19.82	34.17	41.98%	0.64	14.68	26.64
10	2011	11.34	26.98	57.97%	0.71	13.63	23.96
11	2012	18.75	30.97	39.47%	0.79	13.50	23.14
12	2013	32.09	28.74	-11.68%	0.86	11.64	23.00
13	2014	15.15	26.64	43.14%	0.93	11.34	20.79

Graph comparison between the discharge of model with the discharge of observation can be seen in Figure 4 and Figure 5 below:

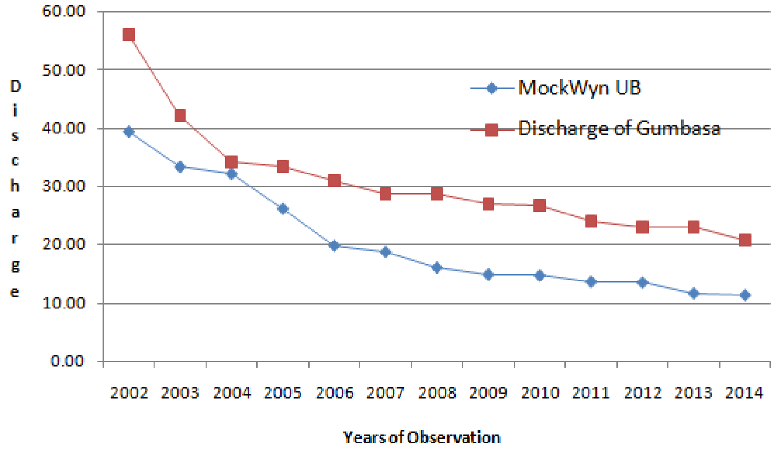

Figure 4 Graph FDC

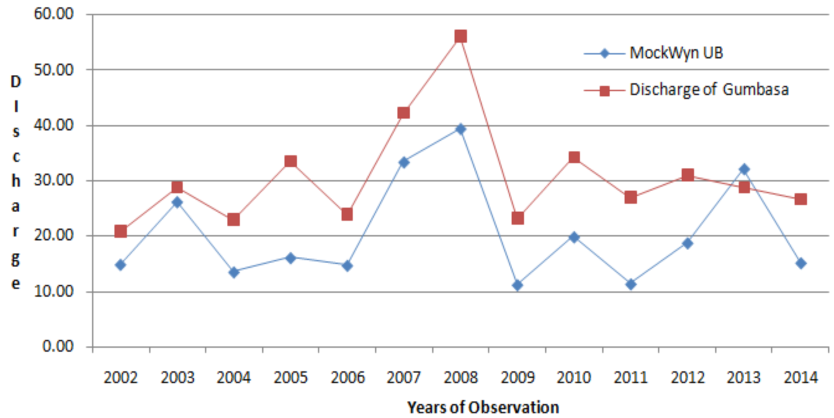

Figure 5. Comparison between discharge of model with discharge of observation

Table 7. Parameter of Statistic RMSE

No.	Year	Discharge of Model (met^3/sec)	Discharge of FJ Mock (met^3/sec)	Discharge of Observation (met^3/sec)	RMSE MockWyn-UB	RMSE FJ Mock
1	2002	14.85	21.86	20.79	1.72	5.81
2	2003	26.15	39.80	28.75	0.75	11.27
3	2004	13.50	15.64	23.00	2.74	3.72
4	2005	16.06	29.43	33.50	5.04	7.04
5	2006	14.68	16.69	23.96	2.68	4.05
6	2007	33.31	48.77	42.19	2.56	13.34
7	2008	39.32	52.22	56.07	4.83	13.68
8	2009	11.19	16.17	23.14	3.45	3.67
9	2010	19.82	23.91	34.17	4.14	5.71
10	2011	11.34	19.29	26.98	4.51	4.26
11	2012	18.75	39.45	30.97	3.53	10.37
12	2013	32.09	56.41	28.74	0.97	16.00
13	2014	15.15	22.02	26.64	3.32	5.40
Amount		266.21	401.66	398.91	40.24	104.33
Average		20.48	30.90	30.69	3.10	8.03

Based on the analysis, the relationship between the discharge and the discharge observation results of research in general form a uniform pattern unless there is a difference in 2013. Which debit calculation result is higher than the discharge observation. As for the correlation coefficient between the discharge and the discharge observation models do not qualify so the calibration data using the facility solver is not done. Thus the calibration is done using Root Mean Square Error (RMSE). Value RMSE the calibration stage is obtained 3.10 %. While the results of analysis model of Mock at this stage values obtained RMSE 8.03 %. The big difference between the discharge and the discharge observation models are affected by several things:

1. Rainfall at the station Kulawi and the station Wuasa greater than other regions. If rainfall is both stations combined percentages exceed the amount of rainfall the three other stations that would affect the calculation of regional rainfall.
2. Existence of Lake Lindu is located in the basin Gumbasa. Lake of Lindu sub-watershed is an area that has 623,35 km^2.

IV. CONCLUSION

Model of discharge MockWyn-UB do not optimal if applied in the watershed Gumbasa. From the analysis of the percentage deviation between the discharge and the discharge observation models above average 20 %. This is caused by the presence of Lindu Lake as a water reservoir so that when it rains, rainwater will be collected first in Lake Lindu, after the water of Lindu Lake full, then the runoff occurs.However the relationship between the discharge and the discharge observation models forming a uniform pattern except in 2013, which is higher than the model discharge observation so as to determine the accuracy of the model discharge test comparisons between models MockWyn-UB model FJ Mock.

Calibration is done by using the Root Mean Square Error (RMSE). MockWyn-UB RMSE value is obtained 3.10%. While the results of model analysis Mock RMSE values obtained 8.03%. From the results above show the RMSE error rate MockWyn-UB models are better than models FJ. Mock.

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REFERENCES

[1]. Mock. F.J, *Land Capability Appraisal in Indonesia: Water Availability Appraisal* (Bogor: UNDP-FAO Of The United Nations., 1973).

[2]. Crawford, Norman H, and Thurin Steven M, *Hydrologic Estimates, National Rural Electric Cooperative Associatio*, (Washington, 1981)

[3]. Nugroho.S.P, S. Adi and H. Soewandito.. Influence Change Of Use Against Land Surface Flow, Sediment and Nutrient. *Journal of Science and Technology BPPT, 4(5)*, 2002.

[4]. I Wayan Sutapa, *Effect of Climate Change Modelling discharge*, Graduate Program Brawijaya University , Malang, 2013.

[5]. Sosrodarsono, Suyono, andTakeda, *Hidrology for Irrigation*. (Jakarta - Publisher Pradnya Paramita, 1983).

[6]. Soemarto C. D, *Hidrology Engineering*. (Publisher Erlangga-Jakarta, 1995).

[7]. Dunne T, and Leopold L B., 1978. *Water in Environtmental Planning* (San Fransisco -W.H. Freeman and Company, 1995).

[8]. Monteith J. L, Evaporation and Environment: 19th Symposium of the Society for Experimental Biology, *Cambridge Univercity Press*, 1965, 205-234.

[9]. Ministry of Settlement and Regional Infrastructure, *River Flow Forecasting*, (Jakarta, 2004).

[10]. Laat P.J.M de, Soil Water-Plant Relations: Lecturer Note, *International Institute for Infrastructural, Hydraulic and Enviromental Engineering (IHE*), Delf, The Netherlands, 2000.