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RELIABILITY PERFORMANCE OF TAMBAK POCOK SMALL DAM, BANGKALAN OF INDONESIA

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ABSTRACT

This paper studied the reliability performance of a small dam. Case of study was at Tambak Pocok Small Dam, Bangkalan City, Madura Island of Indonesia. This small dam was used for suppling domestic demand. The methodology was consisted of analysing discharge using FJ Mock and NRECA Models, because there was no discharge data. Reliability was predicted for the next 20 years later. Discharge data used in this study was begun in the year of 2007. Therefore the reliability performance of dam was predicted until the year of 2026. If using FJ Mock Model, reliability performance of Tambak Pocok Small Dam was 100% from the year of 2007 to 2026, but if using NRECA Model, the reliability performance was 100% only in the year of 2007, but for the other years, the reliability performance was decreasing until 25%. The reliability as above was due to any kind dependable and minimum discharge for each model. The results could be used as consideration in operating the small dam in later long term period.

Keywords: reliability performance, FJ Mock, NRECA

INTRODUCTION

Water resources management and development in Indonesia was targeted to supply any kind of water needs. The water mainly used for supplying daily human needs or domestic uses. The other uses were included irrigation, industry, hydro electrical power, and recreation [1]. Higher cost of hydraulic structures and the limitation of surface water resources intensified an optimum capacity of need and the possibility of reservoir system operation [2].

Management of conservation and demandwere the keys to sustain the use of any kind resources. It was necessary to make attention of a secure and save water future for much of the world that remained elusive due to the rapid increase of population [3]. Planning and management of water resources was not an easy job especially when the problem was as national wide and policy [4]. It became harder and harder if an area is considered unstable or when more influenced factorswere unpredictably. Regional decision making had to be considered to a variety of technical and economical aspects that were needed to be decided. It was an interplayed of information about the system, the methods how to process this information and the interpretation of the results.

Water resources planning and management had the main objective that was to solve the minimum balance of demand and supply of water resources for a specific area [5]. It was taking into account various dimensions like politics, economy, time, space, environment, and other related aspects. Water management also meant as the reconciliation of all preservation of water users, previous of enough water for constantly expanding needs, and related land resources. [6].

Design of dam stoarge was according to the condition of topography, social, and the main factor was water supply and demand. Water supply was meant as the ability of river to supply a quantitative value of discharge along the year, either in the rainy season or dry season which was intended to fulfill design outflow. The whole water demand of design outflow would occur during the operation of dam, which the main component was to reach the target of building dam.

Condition of geography in Bangkalan Regency caused the area was as stoney structure and part of them was included clay. This condition was due to the location which was close to the sea and rainfall was fast to flow down and it was difficult to hold or lengthen time of flow. Therefore the water could be stored in soil and water sources in this area was not be funtioned during the dry season.

MATERIAL AND METHOD

Location of study was in Bangkalan Regency, East Java Province of Indonesia. The study area was falls between south latitude of 6° 51' 39'' to 7° 50' 39'' and east longitude of 112° 40'06" to 113° 08' 04". Number area of Bangkalan Regency was ± 1.260,14 km^2 and it was included 18 districts. Map of location was as in Figure 1 below.

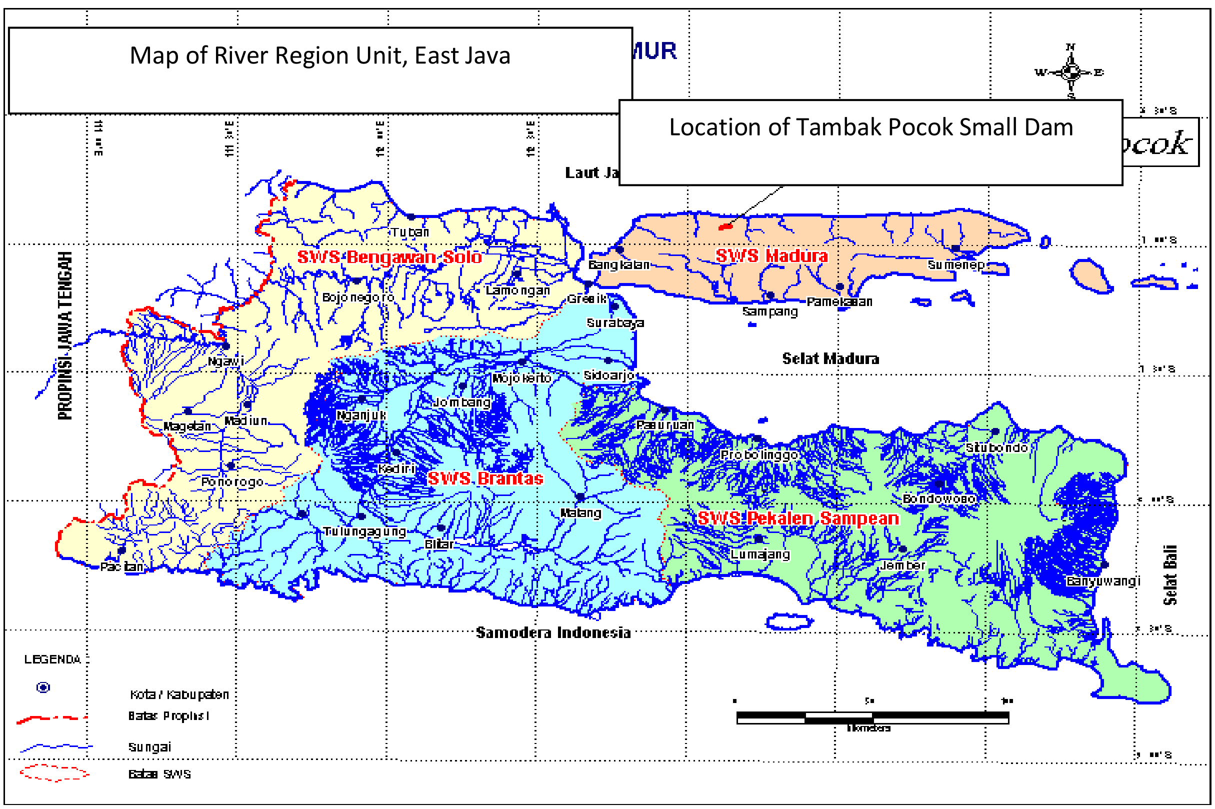


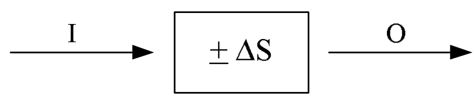
Figure 1.Map of Location

Some data were need for analysing reliability performance of Tambak Pocok Small Dam. Data used in this study were as follow: 1) Daily rainfall in the years of 1996 to 2006 from 3 rainfall stations: Tanjung Bumi, Dupok, and Sepulu; 2) Monthly climate data from 1 station; 3) Data and map of geology from the Center of Geology Research and Development, Bandung of Indonesia: Map of Geology Indonesia System, Lembar Tanjungbumi & Pamekasan 1609-2 & 1608-5 with the scale of 1:100,000; 4) Map of regional topography of Madura, Lembar Tanjung Bumi 1609-211; 5) Data of society condition in Bangkalan Regency in the year of 2006; and 6) Technical data of Tambak Pocok Small Dam.

The methodologies of this study were as follow: 1) To analyse monthly average rainfall; 2) To analyse potential evapotranspiration using modified standard of FAO: Penmann Method; 3) To predict the parameter of FJ Mock and NRECA due to the data of watershed characteristic; 4) To generate available discharge data of FJ Mock and NRECA results during 9 years using Thomas-Fiering Method; 5) To analyse domestic water demand; 6) To simulate the storage of Tambak Pocok small dam; and 7) To analyse reliability performance of Tambak Pocok for operation due to the prediction of period.

Principal of water balance

The principal of water balance showed the balancing between inflow and outflow of a sub-system. Generally, the formula of water balance was as follow: [7] [8]



$$I = O \pm \Delta S \qquad (1)$$

Note: I = inflow; O = ourflow; and ΔS = storage change

Method of NRECA

Method of NRECA (National Rural Electric Cooperative Association) was developed by Norman H. Crowford (USA) in the year of 1985. This method was the simplification of Standard Watershed Model IV (SWM). Model of SWM had 34 parameters, but model of NRECA only used 5 parameters. This model could be used for analysing monthly discharge due to monthly rainfall and based on water balance in watershed. The equation used in NRECA Model was based on the concept: rainfall – actual evapotranspiration + storage change = runoff, total of river discharge was analysed with the formula as follow: [9][10]

Q = (GF + DRF) x A (2) Note:

A = number area (km^2)

DRF = direct runoff (mm)= excm (1-PSUB)

Exc = surplus of humidity

Exc. = exrat x (P-AET)

GF = groundwater (mm)= GWF x (PSUB x Exc. = GWS)

exrat = ratio of humidity surplus = 0,5 x (1 + ((Sr-1)/0,52)), if Sr > 0 and = 0, if Sr < 0

Sr = coefficient of storage = SMS/NOM

SMS = storage of soil humidity ; NOM = capacity of humidity storage

= 100 + 0,2 x Ra; Ra = yearly average rainfall (mm)

P = monthly rainfall (mm)

CROPF = factor of perspiration vapour

Kl = (P/PET) x (1 -0,5 Sr) + 0,5 Sr

AET = actual evaporation = CROPF x PET, if P/PET> 1 or Sr >2

= (kl x PET) x CROPF, if P/PET < 1 or Sr < 2

Method of FJ Mock

The formula of rainfall which reached soil surface was as follow: [9][10][11]

Ds = P – Et (3)

Note

Ds = rainfall which reached soil surface (mm/day)

P = rainfall (mm/day)

Et = limited evapotranspiration (mm/day)

Groundwater Storage: [11]

$Vn = k \cdot V_{n-1} + ½ (1 + k) \cdot In$ (4)

$DVn = Vn – V_{n-1}$ (5)

Note:

Vn = volume of groundwater on the month of n

V_{n-1} = volume of groundwater on the month of (n - 1)

K = qt/qo =factor of catchment area recession

qt = groundwater on the month of t

qo = groundwater on the beginning of month (month ofzero)

In = infiltration on the month of n

DV_{n-1}= volumechange of groundwater

RESULT AND DISCUSSION

Simulation of Small Dam Storage Balance

Simulation of storage balance was included operation of one year or more. In the process of simulation, operation pattern would be divided into a number of period, begun from the monthly, 15 daily, or 10 daily of time periods. Time period used in this study was monthly operation.Simulation of reservoir balance was as one of some items of evaluation of available water supply [4][8]. Discharge data had been generated for 20 years. Scenario of balance simulation was carried out one by one due to the changes of water domestic demand during the prediction of 20 years and using the methods of NRECA and FJ Mock. In the beginning process of reservoir simulation, Tambak Pocok Small Dam was assumed full with effective storage capacity was 2,233.38 m^3.

Simulation of reliability performance

A small dam could be categoried as good reliability performance if the dam was able to garrantie minimum demand of needs. In the simulation of reliability performance of small dam would be predicted what available storage capacity of small dam could fulfill the whole demands along the year with certain failure risk [8]. Analysis of reliability performance was analysed due to monthly operation of the small dam what it was fail or success operated to fulfill plan of demand in simulation analysis of small dam storage. Simulation of Q_{50}, Q_{70}, Q_{80}, Q_{90}, and Q_{min} was presented as in Table 1, 2, 3, 4, and 5 below.

Table 1.Simulation of 50% Discharge ($Q_{50\%}$)

Discharge of NRECA									
No	Year	Water Supply (m^3)	Water Demand (m^3)	Serviced Population (person)	Different (m^3)	Information	Reliability Performance (%)	Irrigation Water Demand (m^3)	Serviced number of area (ha)
1.	2007	627,386.18	63,598	2,904	563,789	surplus	100.00	18921.60	29.80
2.	2011	627,386.18	69.051	3,153	558,335	surplus	100.00	18,921.60	29.51
3.	2016	627,386.18	76.541	3,495	550.846	surplus	100.00	18,921.60	29.12
4.	2021	627,386.18	84.841	3,874	542.546	surplus	100.00	18.921,60	28.68
5.	2026	627,386.18	94.039	4,294	533,348	surplus	100.00	18,921.60	28.19

Discharge of FJ Mock									
No	Year	Water Supply (m^3)	Water Demand (m^3)	Serviced Population (person)	Different (m^3)	Information	Possibility of Failure (%)	Irrigation Water Demand (m^3)	Serviced number of area (ha)
1.	2007	1,023,216.77	63,598	2,904	959,619	surplus	100.00	18,921.60	50.72
2.	2011	1,023,216.77	69.051	3,153	954,166	surplus	100.00	18,921.60	50.43
3.	2016	1,023,216.77	76,541	3,495	946,676	surplus	100.00	18,921.60	50.04
4.	2021	1,023,216.77	84,841	3,874	938,178	surplus	100.00	18,921.60	49.60
5.	2026	1,023,216.77	94.039	4,294	929,178	surplus	100.00	18,921.60	49.11

The end changes of storage capacity in each year process of simulation had an interdependence [8]. For example, end storage of small dam on December 2007 would fill as the storage in the beginning of January 2008 in so fort until the end of simulation period during 20 years. Initial storage capacity was very important because it was very influantial to the success or failure of storage simulation process [8]. Based on 20 years of simulation, FJ Mock Method was able to fulfill 100% of operation process. But if it was used NRECA Method, it was failed operation in the year of 2004, but it was full success in the year of 2007-2008 and the next year was decreasing until 42% in the year of 2026.

Table 1 showed that there was different water supply between the result of NRECA and FJ Mock. The result of FJ Mock was higher than NRECA, so that serviced number of irrigation area using FJ Mock Method was larger than NRECA, but it was the same for serviced population. Where by the reliability performance of storage had dependable of 100% for the two method results. It was presented the surplus information for all of the years.

Table 2.Simulation of 70% Discharge ($Q_{70\%}$)

Discharge of NRECA

No	Year	Water Supply (m^3)	Water Demand (m^3)	Serviced Population (person)	Different (m^3)	Information	Reliability performance (%)	Irrigation Water Demand (m^3)	Serviced number of area (ha)
1.	2007	277,294.26	63,598	2,904	213,697	surplus	100.00	18921.60	11.30
2.	2011	277,294.26	69.051	3,153	208,244	surplus	100.00	18,921.60	11.01
3.	2016	277,294.26	76.541	3,495	200.754	surplus	100.00	18,921.60	10.61
4.	2021	277,294.26	84.841	3,874	192.454	surplus	100.00	18.921,60	10.61
5.	2026	277,294.26	84.841	4,294	183,256	surplus	100.00	18,921.60	9.69

Discharge of FJ Mock

No	Year	Water Supply (m^3)	Water Demand (m^3)	Serviced Population (person)	Different (m^3)	Information	Possibility of failure (%)	Irrigation Water Demand (m^3)	Serviced number of area (ha)
1.	2007	657,667.54	63,598	2,904	594,070	surplus	100.00	18,921.60	31.40
2.	2011	657,667.54	69.051	3,153	588,617	surplus	100.00	18,921.60	31.11
3.	2016	657,667.54	76,541	3,495	581,127	surplus	100.00	18,921.60	30.72
4.	2021	657,667.54	84,841	3,874	572,827	surplus	100.00	18,921.60	30.28
5.	2026	657,667.54	94.039	4,294	563,629	surplus	100.00	18,921.60	29.79

Table 2 showed that there was also the different water supply between the result of NRECA and FJ Mock. The result of FJ Mock was higher than NRECA, so that serviced number of irrigation area using FJ Mock was larger than NRECA, but it was the same for serviced population. Where by the reliability performance of storage had dependable of 100% for the two method results. It was presented the surplus information too for all of the years.

Table 3.Simulation of 80% Discharge ($Q_{80\%}$)

Discharge of NRECA										
No	**Year**	**Water Supply (m^3)**	**Water Demand (m^3)**	**Serviced Population (person)**	**Different (m^3)**	**Information**	**Reliability performance (%)**	**Irrigation Water Demand (m^3)**	**Serviced number of area (ha)**
1.	2007	118,253.57	63,598	2,904	54,656	surplus	100.00	18,921.60	2.89
2.	2011	118,253.57	69.051	3,153	49,203	surplus	100.00	18,921.60	2.61
3.	2016	118,253.57	76.541	3,495	41,713	surplus	100.00	18,921.60	2.21
4.	2021	118,253.57	84.841	3,874	33,413	surplus	100.00	18,921.60	1.77
5.	2026	118,253.57	94.039	4,84	24,215	surplus	100.00	18,921.60	1,28
Discharge of FJ Mock									
No	**Year**	**Water Supply (m^3)**	**Water Demand (m^3)**	**Serviced Population (person)**	**Different (m^3)**	**Information**	**Possibility of failure (%)**	**Irrigation Water Demand (m^3)**	**Serviced number of area (ha)**
1.	2007	468,726.83	63,598	2,904	405,129	surplus	100.00	18,921.60	21.42
2.	2011	468,726.83	69.051	3,153	399,676	surplus	100.00	18,921.60	21.13
3.	2016	468,726.83	76,541	3,495	392,186	surplus	100.00	18,921.60	20.73
4.	2021	468,726.83	84,841	3,874	383,886	surplus	100.00	18,921.60	20.29
5.	2026	468,726.83	94.039	4,294	374,688	surplus	100.00	18,921.60	19.81

Table 3 showed that there was also the different water supply between the result of NRECA and FJ Mock. The result of FJ Mock was higher than NRECA, so that serviced number of irrigation area using FJ Mock was larger than NRECA, but it was the same for serviced population. Where by the reliability performance of storage had dependable of 100% for the two method results. It was presented the surplus information too for all of the years.

Table 4.Simulation of 90% Discharge ($Q_{90\%}$)

Discharge of NRECA									
No	Year	Water Supply (m^3)	Water Demand (m^3)	Serviced Population (person)	Different (m^3)	Information	Reliability performance (%)	Irrigation Water Demand (m^3)	Serviced number of area (ha)
1.	2007	61,848.07	63,598	2,825	-1,750	deficit	97.28	0.00	0.00
2.	2011	61,848.07	69.051	2,825	-7,203	deficit	89.60	0.00	0.00
3.	2016	61,848.07	76.541	2,825	-14,692	deficit	80.83	0.00	0.00
4.	2021	61,848.07	84.841	2,825	-22,993	deficit	72.92	0.00	0.00
5.	2026	61,848.07	84.841	2,825	-32,191	deficit	65.79	0.00	0.00
Discharge of FJ Mock									
No	Year	Water Supply (m^3)	Water Demand (m^3)	Serviced Population (person)	Different (m^3)	Information	Possibility of failure (%)	Irrigation Water Demand (m^3)	Serviced number of area (ha)
1.	2007	232,734.45	63,598	2,904	169,137	surplus	100.00	18,921.60	8.94
2.	2011	232,734.45	69.051	3,153	163,684	surplus	100.00	18,921.60	8.66
3.	2016	232,734.45	76,541	3,495	156,194	surplus	100.00	18,921.60	8.26
4.	2021	232,734.45	84,841	3,874	147,894	surplus	100.00	18,921.60	7.82
5.	2026	232,734.45	94.039	4,294	138,696	surplus	100.00	18,921.60	7.34

Table 4 showed that there was also the different water supply between the result of NRECA and FJ Mock. The result of FJ Mock was higher than NRECA, so that serviced population and serviced number of irrigation area using FJ Mock was larger than NRECA. There was deficit if using NRECA Method, but the result of FJ Mock was remain surplus of the whole years, but serviced number of irrigation area was decreasing compared with the two kinds of discharge: 50% and 70%. Because of deficit condition if using NRECA Method, so that serviced number of irrigation area was zero or no irrigation area could be supplied. The reliability performance of storage using FJ Mock was higher than NRECA in all of years.

Table 5.Simulation of Minimum Discharge (Q_{min})

Discharge of NRECA

No	Year	Water Supply (m^3)	Water Demand (m^3)	Serviced Population (person)	Different (m^3)	Information	Reliability performance (%)	Irrigation Water Demand (m^3)	Serviced number of area (ha)
1.	2007	61,848.07	63,598	2,825	-1,750	deficit	97.28	0.00	0.00
2.	2011	61,848.07	69.051	2,825	-7,203	deficit	89.60	0.00	0.00
3.	2016	61,848.07	76.541	2,825	-14,692	deficit	80.83	0.00	0.00
4.	2021	61,848.07	84.841	2,825	-22,993	deficit	72.92	0.00	0.00
5.	2026	61,848.07	94.039	2,825	-32,191	deficit	65.79	0.00	0.00

Discharge of FJ Mock

No	Year	Water Supply (m^3)	Water Demand (m^3)	Serviced Population (person)	Different (m^3)	Information	Possibility of failure (%)	Irrigation Water Demand (m^3)	Serviced number of area (ha)
1.	2007	232,734.45	63,598	2,904	169,137	surplus	100.00	18,921.60	8.94
2.	2011	232,734.45	69.051	3,153	163,684	surplus	100.00	18,921.60	8.66
3.	2016	232,734.45	76,541	3,495	156,194	surplus	100.00	18,921.60	8.26
4.	2021	232,734.45	84,841	3,874	147,894	surplus	100.00	18,921.60	7.82
5.	2026	232,734.45	94.039	4,294	138,696	surplus	100.00	18,921.60	7.34

Table 5 showed that Q_{min} of FJ Mock result was 100% success in operation, but NRECA result was 100% success in the beginning but it was decreasing until 25% in the year of 2026. $Q_{min}$was also analysed because it had high probability in operation due to climate and geology condition in location of study. There was drought in dry season. NRECA method was not satisfied because the structure of model was based on the soil moisture zone and it had been very influantial by season. Therefore it was difficult to produce optimal simulation of discharge.

Based on the analysis as above, for surplus water on Q_{50}, the ability of area could be fulfilled by the two methods. There was number area of 49 ha for FJ Mock result and 28 ha for NRECA result. For the discharge of Q_{70}, number area of FJ Mock was 29 ha and for NRECA was 9 ha; for Q_{80}: FJ Mock was 19 ha and NRECA was 1.3 ha; for Q_{90}: FJ Mock was 7 ha and NRECA was 0 ha; and for Q_{min}: FJ Mock was 2.7 ha and NRECA was 0 ha.

CONCLUSION

Based on the analysis as above, it was conclused that:

1. The average discharge of NRECA result was 698,487.63 m^3 and FJ Mock was 1,193,856,03 m^3, for dependable discharge of 80%: NRECA was 118,253.57 m^3 and F.J Mock was 468,726.83 m^3, for dependable discharge of 90%: NRECA was 61,848.07 m^3 and F.J. Mock was 232,734.45 m3; and for minimum discharge: NRECA was 39,722.01 $m^3$and F.J Mock was 146,567.24 m^3.
2. Total of outflow volume from Tambak Pocok small dam for domestic supply in the beginning operation of 2007 was 63,597.60 $m^3$for supplying 2904 population, until 2016 was 76,540,50 m^3 forsupplying 3,495 population, but for 20 years later, the volume in the year of 2026 was 94,038.60 $m^3$for supplying 4,294 population.
3. FJ Mock result showed that reliability performance of Tambak Pocok small dam for all discharge condition was 100% until 2026, but for NRECA result, the reliability performance of 100% was not occured in Q_{min}, so that it was suggested to supply the demand from the other sources.

REFERENCES

1. Rispiningtati. 2010. Model of Water Allocation and Price for Multifunctional Reservoir. *International Journal of Academic Research*, Vol. 2, No. 6: 304-307
2. Sattari, Mohammad Taghi; Saleyman, Kodal; and Fazli, Oztork. 2006. Application of Deterministic Mathematical Method in Optimizing The Small Irrigation Reservoir Capacity. *Journal of AkdenizUniversitesi Ziraat Fakoltesi Dergisi*. 19(2): page 261-267
3. INWRDAM. 2001. Decision Support System in the Field of Water Resources Planning And Management. *Published on line in* http://www.nic.gov.jo/inwrdam/dss.html. March 12, 2001.
4. Pavoni, B; A. Voinov and N. Zhavora. 2001. Basin (Watershed) Approach As A Methodological Basis for Regional Decision Making And Management in the EX USSR. *Published on line in*http://helios.unive.it/%7Eintas/gaboart.html. March 12, 2001.
5. Limantara, Lily Montarcih. 2010. Optimization of Water Needs at Kepanjen Dam and Sengguruh Dam, East Java, Indonesia. *International Journal of Academic Research*, Vol. 2 No.5: 216-220
6. Suhardjono; Limantara, Lily Montarcih; Soemarno; and Nurhayati, Eko. 2010. Discharge Model Based on Water Balance in Brantas Upstream River, Indonesia. *Journal of Economics and Engineering*, No.3: 38-41
7. Montarcih, Lily and Soetopo, Widandi. 2011. *Manajemen Sumberdaya Air*. CV Lubuk Agung. Bandung.
8. Mc, Mahon & Mein. 1978. *Reservoir and Capacity Yield*. New York: Elsevier Scientific Publishing Company.
9. Montarcih, Lily. 2010. *Hidrologi Praktis*. C :Lubuk Agung. Bandung
10. Asdak, C. 2004. *Hidrologi dan Pengelolaan Daerah Aliran Sungai.* Yogyakarta: Gadjah Mada University Press.
11. Mock F. J. 1973. *Land Capability Apraisal Indonesia Water Avaitlability Apraisal.* Bogor