Evaluation of Reservoir Capacity and Reliability for urban water purpose in Dili, Timor Leste

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ABSTRACT Water shortages have an impact on all aspects of life in Dili, Timor Leste. To support the government vision and program in the water sector, a study on the development of water resource management strategies has been carried out. The priority strategy has resulted in that is developing water resource infrastructure to meet urban water demand. One action plan of this strategy is to build reservoir infrastructure. The purpose of this study is to evaluate the construction of a small or large reservoir to meet the water demand in Dili. Evaluation of the strategy implementation plan of the development of the reservoirs in the Beemos and Becora Rivers through analysis of the reliability and capacity of the reservoir using a simulation model of water release standard operating rules method. Water balance simulation results show that the reliability of clean water services from the two small reservoirs of Beemos and Becora cannot reach 100%, due to the limited capacity of the reservoir. The results of capacity optimization of large Beemos Reservoir show that the potential for inflow can be utilized 90%, therefore it can meet urban water demand until 2030. Although the simulation results show a good indication, the government still must carry out a detailed feasibility study in the upstream area before it is implemented. The development of a large reservoir can be recommended for implemented in the development of water resources to meet water demand in Dili therefore can support Timor Leste's targets or vision in the water sector and the Sustainable Development Goals in the clean water and sanitation sector.

KEYWORDS: water resource infrastructure; operating rules; reservoir simulation; reliability; reservoir capacity

1. INTRODUCTION

The Government of Timor Leste has set safe access to drinking water as one of the priority agendas as described in the 2011-2030 Strategic Development Plan (SDP), which is expected to have access to safe drinking water for 24 hours to reach 100% by 2030 (universal access) (Gov.TimorLeste, 2011). Timor Leste is one of the countries that has achieved the Millennium Development Goals (MDG) target for urban water supply. According to the WHO / UNICEF Joint Monitoring Program (JMP), the total coverage for increasing urban water supply in 2015 was 91%. This figure has exceeded the MDG target for urban water supply, which is 88% (JMP, 2017). Although Timor Leste achieved the MDG target, water distribution to the household in Dili remains low. Based on the 2015 Timor Leste census data, Dili households have a 25% connection to tap water, 15% of residents still access public taps, bore wells 11%, and protected springs 1%.

The Government of Timor Leste still lacks data to formulate more specific strategies relating to the management of water resources in Timor Leste (ADB, 2015). To support the vision of Timor Leste in the water sector, the study to developed water resource management strategies in Dili was carried out in 2019 (Takeleb et al., 2020). The process to determine water resource management strategies was involved water resources stakeholders and decision-makers and analyzed the result using the decision-making method (Takeleb et al., 2020). The results of the SWOT analysis were showing that the highest weighting value in the weakness factor that influenced in water resource management system in Dili was water demand is higher than water availability. While the first and second opportunity with the highest weight is the development plan for surface water resources and the development of water resources infrastructure (Takeleb et al., 2020). Based on the decision support system analysis, the results of the formulation of strategic priorities show that the first and second priorities in implementation are the development of water resources infrastructure and the development of surface water sources (Takeleb et al., 2020). This planning strategy is very appropriate to be implemented by the Timor Leste government associated with an effort to increasing water sources to meet urban water needs. However, before implemented it is necessary to evaluate the implementation of this priority strategy. In the strategy implementation framework, several actions have been defined and will be implemented about the priority strategy. The first work action is the construction of reservoir infrastructure in the Comoro watershed to develop surface water sources to meet the water needs of Dili.

Water resource infrastructure such as dam and reservoir are an infrastructure that is recommended to be built in the Comoro River Basin to solve water demand problem. In some developing countries, the development of reservoirs and dams for the future is a management strategy for decision-makers to solve the water availability problem (Elarabawy et al., 1998; Ndiritu et al., 2017; Yang et al., 2019). The construction of reservoirs for the development of river water resource is associated with low of river flow and improves the river stream condition particularly in the river during the dry season(Nugroho, 2015; Yang et al., 2019). Dili has a tropical climate with annual wet and dry seasons. The annual rainfall amount varies yearly from 481.2 mm to 1,716.4 mm (MPSTL, 2016). Low rainfall in the Dili area, puts more pressure on water resources availability in the Comoro watershed (ADB, 2015; DNGRA, 2016; Pinto et al., 2015; Takeleb et al., 2018). The construction of new reservoirs must first be evaluated for their reliability and capacity based on the available river discharge.

The construction of the reservoir is a part of surface water system development. The construction of the reservoir is a part of surface water system development. When water availability of surface water is has a variability, it needs to control and regulate the water to meet the demand (Mays and Tung, 1992). Reservoirs have a function to control and regulate the flow. Dams are constructions that can hold or restrict the flow of a river or underground water. The reservoir is a construction built next to a dam to accommodate the flow. Reservoirs can reduce flooding but also provide water for activities such as irrigation, human consumption, industrial use, aquaculture, and navigation capabilities (Mays and Tung, 1992; Nugroho, 2015). International standards (including the International Commission on Large Dams, ICOLD) define large dams as higher than 15 m from the lowest general foundation to the crest (Shah and Kumar, 2008). The reservoir capacity is more than one MCM and the crest length is more than 500 m. The U.S. Fish and Wild Life Service, under its Dam Safety Programmed, has adopted the following criteria for defining small dams are structures that are less than 13 m high or that impound less than 1.2e106 m3 of water (Shah and Kumar, 2008). The benefit of a reservoir development project is dependent on the size and operation of the reservoir.

Some indicators to assess the reservoir operation performance can include reliability, resilience, and vulnerability (Hariri-Ardebili, 2018; Ndiritu et al., 2017). The performance of reservoir operations is a reservoir indicator in operation to meet water demand. One important issue in assessing reservoir operation performance is the operating rules of reservoirs. Water researchers have considered the optimization of reservoir operating rules and the non-linear optimization algorithms in reservoir operation are rarely used in practical application (Geressu and Harou, 2019; Mudjiatko et al., 2015; Ndiritu et al., 2017; Ren et al., 2019). The operating rule was used in Hluhluwe dam, South Africa to assess the reservoir yield and hydroelectricity, and municipality demand. It is showing that realistic operating rules and optimizing have improved the operation of the dam (Ndiritu et al., 2017). The operating rules were used in the case of reservoir system expansion scheduling in the Blue Nile hydropower reservoir. The result has shown that operation rules help decision-makers to consider multiple objectives in a reservoir system expansion schedule (Geressu and Harou, 2019). The operating rules provide a management template for decision-making on multi-purpose water reservoirs under climate change and complex human activities (Ren et al., 2019). System optimal operation of reservoirs provides a feasible way to reduce the cost and risk associated with reservoir management and balance the beneficial relationship between the competing objectives (Mays and Tung, 1992). Operating rules were used to optimize the reliability of small reservoir for irrigation and raw water demand in Java and Sumatra (Jaya, 2019; Mudjiatko et al., 2015). This study aims to evaluate the capacity and reliability of a new reservoir with the objective to meet urban water demand in Dili. The Operating rules will be used as a method to optimize the small and large reservoir with one objective. The characteristic rainfall, evaporation, and flow in the watershed are influenced the reservoir reliability.

2. MATERIAL AND METHOD

2.1. Location

The purposed small reservoir location will be developed in 2 rivers, the Beemos, and Becora rivers. Beemos and Becora river is the sub-watersheds in the Comoro watershed. The area of Beemos is 43.46 km^2 and Becora is 18.01 km^2.

To date, the water of Beemos and Becora river has been supplied to Dili. Water from both rivers is elevated using check dams and collected by intake to the tank before doing the distribution to the city. The location of the reservoir can be seen in Figure 1. The catchment boundary was downloaded using ALOS PALSAR's Digital Elevation Model (DEM) data with a resolution of 12.5 m from the official National Aeronautics and Space Administration (NASA) website, https://vertex.daac. asf.alaska.edu/.

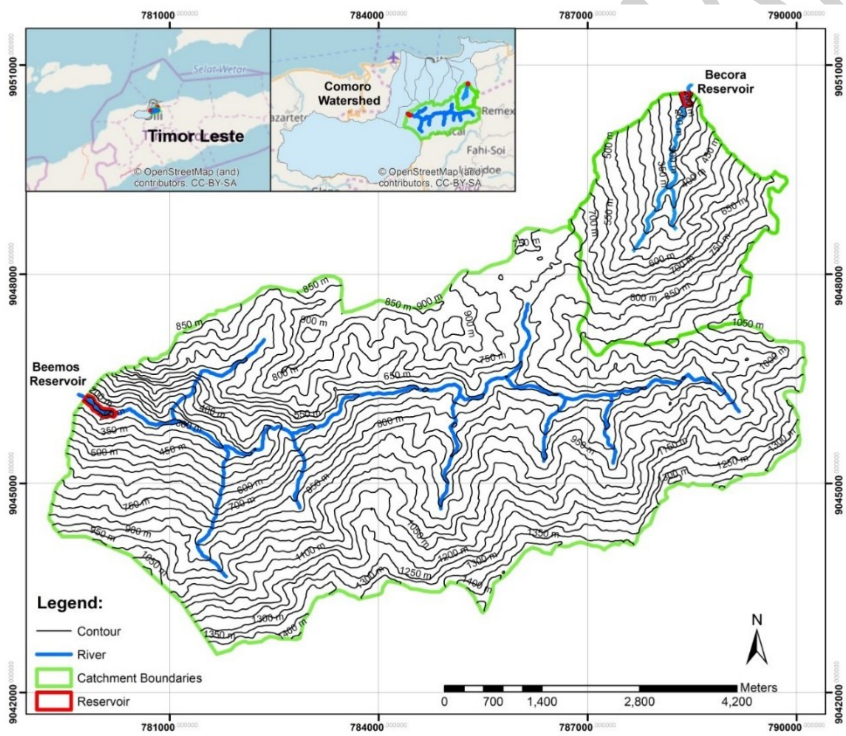

Figure 1. Location of purposed Beemos & Becora reservoir

2.2. Water availability

The rainfall-runoff method is used to estimate the surface water availability based on the unavailability of discharge recorded data in the Beemos, Becora, Maloa, and Culuhun rivers. Rainfall data for the past

10 years (2006-2015 has obtained from 6 rainfall station. Three stations located at upstream of Comoro namely Fasenda, Ermera and Aileu station and other three stations located in downstream namely Dare, Remexio and Aeroportu Dili station. The rainfall-runoff Mock method in principle states that rain occurs and falls on the catchment area, some will be lost due to evapotranspiration, some will immediately become runoff or direct runoff, and some will go into the ground or infiltrate (Mock, 1973). The availability of water is also supplied by groundwater. The groundwater availability has obtained from the production data of 25 artesian wells made in the city of Dili (ADB, 2015). The monthly dependable flow of 4 river and average production of artesian wells can be seen in Table 1.

Table 1. Monthly dependable flow and groundwater

Month	Q_{90} Beemos (L/sec)	Q_{90} Maloa (L/sec)	Q_{90} Culuhun (L/sec)	Q_{90} Becora (L/sec)	Groundwater (L/sec)	Total (L/sec)
Jan	25.55	9.699	4.905	1.083	306.94	348.18
Feb	55.11	8.169	4.932	7.795	326.49	402.50
Mar	38.69	8.795	7.511	3.896	315.48	374.37
Apr	53.30	11.170	6.364	21.494	301.62	393.95
May	29.26	7.934	13.590	2.800	307.62	361.21
Jun	13.43	4.653	0.733	4.369	326.11	349.30
Jul	8.45	0.265	4.140	2.642	312.67	328.17
Ags	3.19	0.000	0.215	1.067	320.11	324.59
Sep	0.81	0.707	1.310	0.740	323.54	327.10
Oct	0.81	0.614	0.391	0.729	315.63	318.18
Nov	3.68	0.539	0.840	2.343	308.97	316.37
Des	4.78	6.549	5.241	9.772	300.17	326.52

2.3. Water Demand

Dili municipal is the capital of Timor Leste. The total population in Dili is 265,000 people. The water demand is used as the target release/outflow in simulation. The water demand is based on the domestic and non-domestic purposes in Dili. Data from the National Water and Sanitation Directorate (Direcao National Saneamento e Agua, DNSA) noted that in 2015, 94% population of Dili registered to get water connections for domestic and non-domestic purposes. The urban water use for domestic purposes is for drinking, washing, and toilet. For non-domestic purposes are for institutions such as schools, hospitals, and offices for commercial needs such as hotels, markets, restaurants, and small industries. The Dili average water demand from 2015 to 2030 can be seen in Figure 2.

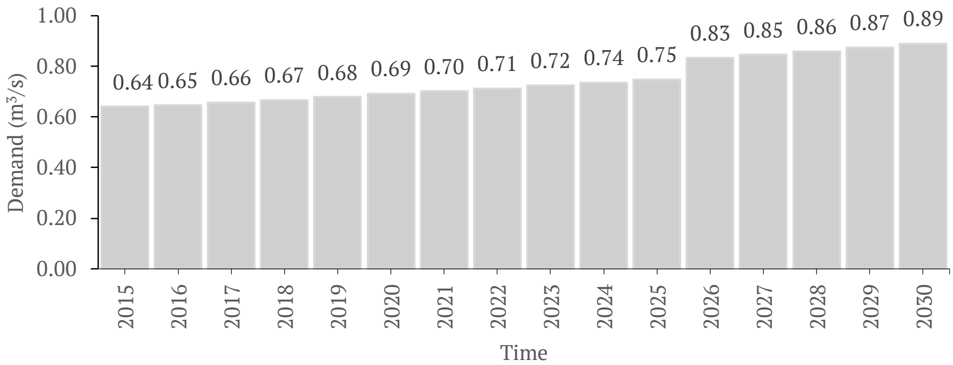

Figure.2. Average Water Demand

2.4. Netto Demand

Net water demand will be used in the simulation as a target release or water demand that is required to be met by reservoirs. The net water demand is the water demand that cannot be provided by existing water resources. Dili's water resources are provided by 4 rivers and groundwater. In the analysis of water requirements in the Beemos reservoir, the discharge from the Beemos river is not included in the analysis. In Becora reservoir simulation, the discharge from the Becora river is also not including in the analysis. The simulation scenario for Beemos reservoir releases with water needs is 60% of the total water needs while 40% of water needs will be released by Becora reservoirs. In the calculation scenario of Beemos reservoir with a large capacity, it is assumed to serve 100% of the city's water needs.

Table 2. Netto Demand

Year	60% monthly net demand (m^3/sec)	40% monthly net demand (m^3/sec)	100% monthly net demand (m^3/sec)
2021	0.222	0.148	0.364
2022	0.226	0.151	0.373
2023	0.231	0.154	0.381
2024	0.236	0.157	0.389
2025	0.271	0.181	0.447
2026	0.276	0.184	0.456
2027	0.281	0.187	0.464
2028	0.286	0.191	0.472
2029	0.291	0.194	0.480
2030	0.387	0.258	0.640

2.5. Stream flow Generation

To generate Beemos and Becora stream flow, Thomas- Fiering approach was used in this study. Thomas-Fiering's Model is more reliable in streamflow data and more able to generate sequences of daily flows of a historic record (Alfa et al., 2018; Vaghela and Vaghela, 2014). The model was able to generate synthetic data for a required period which was similar to the original data. Algorithm model of Thomas-Fiering's can be given as (Arselan, 2011; Vaghela and Vaghela, 2014)

$$X_{i+1} = \bar{X}_{j+1} + b_j(X_i - \bar{X}_j) + t_i S_{j+1}\sqrt{(1 - r_j^2)} \quad (1)$$

$$b_j = r_j \frac{S_{j+1}}{S_j} \quad (2)$$

$$r_j = \frac{C_1}{C_2} \quad (3)$$

$$C_1 = \sum_i (X_{ji} - \bar{X}_j)(X_{j+1,i} - \bar{X}_{j+1}) \quad (4)$$

$$C_2 = \sqrt{\sum_i (X_{ji} - \bar{X}_j)^2 \sum_i (X_{j+1,i} - \bar{X}_{j+1})^2} \quad (5)$$

where: Xi+1 and Xi are the monthly stream value to be simulated for i+1 month and month i, and are mean monthly values during the j+1 and jth month; bj is regression coefficient in j+1 from j month; is the serial correlation coefficient between values in jth and j+1 month; Sj, Sj+1 are the standard deviations of monthly values in j and j+1 months. ti is a random normal deviate with zero mean and unit variance.

The discharge data of Beemos and Becora river from 2006 to 2015 was generating from 2021 to 2030. The serial correlation coefficient and the monthly mean and standard deviation can be seen in figure 3 and figure 4. Generate inflow can be seen in Figure 5.

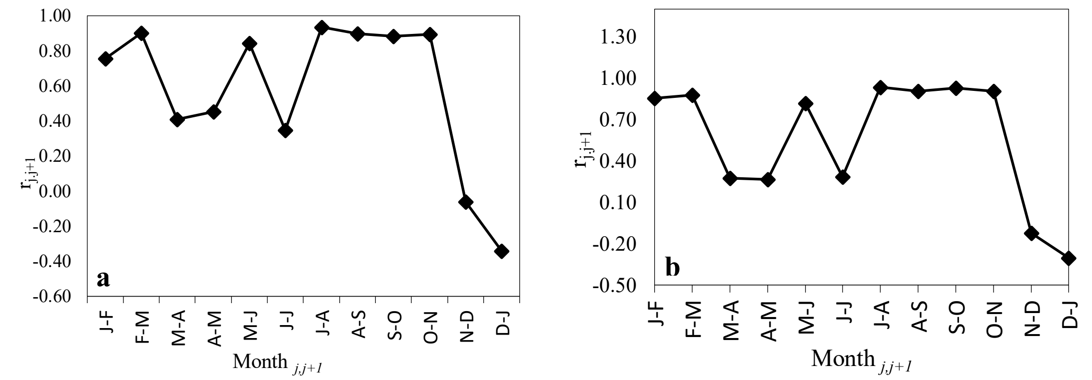

Figure.3. Serial Correlation coefficients a) Beemos; b) Becora

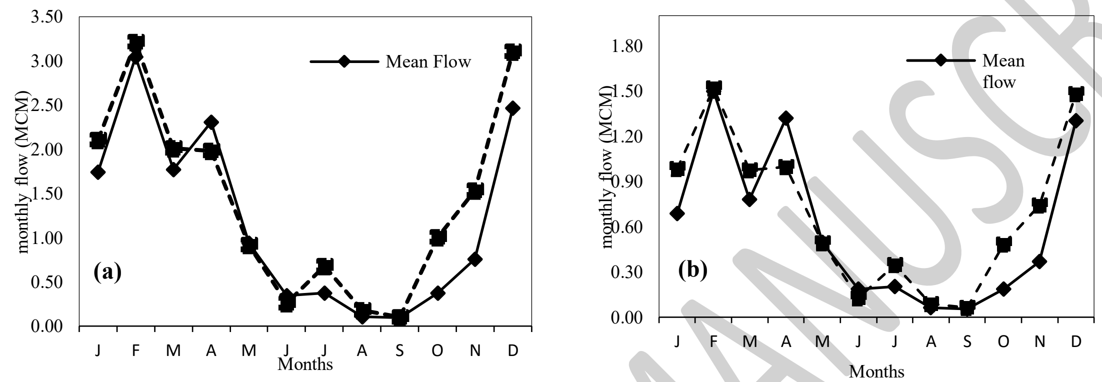

Figure 4. The monthly mean and standard deviation flow (a) Beemos; (b) Becora

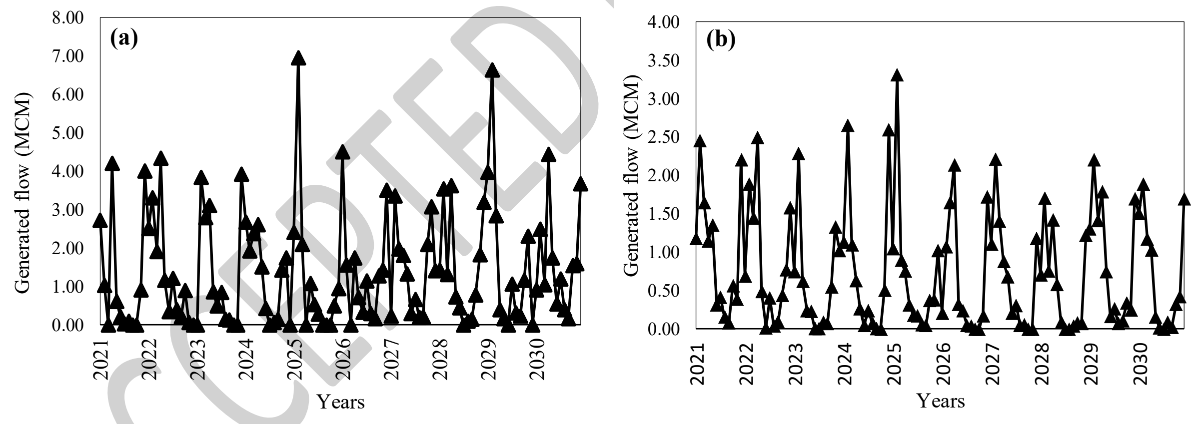

Figure 5. The monthly generated flow (a) Beemos; (b) Becora

2.6. Characteristics of reservoirs

Reservoir characteristic curves are required to determine the relationship between elevation, area of the reservoir, and reservoir storage. The characteristic of Beemos and Becora reservoirs as shown in Figure 4.

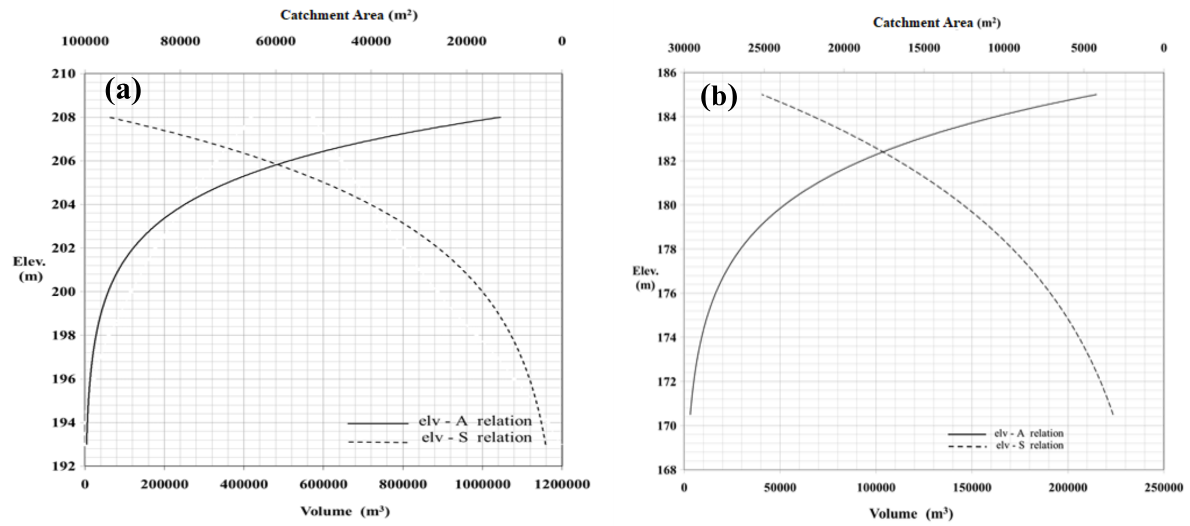

Figure 6. small reservoir characteristic curve (a) Beemos; (b) Becora

The elevation-volume relationship of Beemos and Becora reservoirs used the power equation which is equations 5 and 6. The elevation and total area relationship also used the power equation as in equations 7 and 8.

$$S_{Beemos} = 1256.8(Elev-192,5)^{2,1944} \quad (6)$$

$$S_{Becora} = 357.19(Elev-154)^{1.9567} \quad (7)$$

$$A_{Beemos} = 1565,3(Elev - 192,5)^{1,3503} \quad (8)$$

$$A_{Becora} = 548.83(Elev - 154)^{1,0358} \quad (9)$$

where S is reservoir volume (MCM), Elev is the elevation (MSL) and A is the total wetted area (Ha).

2.7. Operating Rules

The purpose of operating rules for water resources systems is to manage the water that comes out of the system. Specific simulations to determine the limitations of river water availability systems and water demand systems in service areas Reservoir simulation objective is to determine reservoir operation over a given period with known inflow and outflow throughout the system. Reservoir simulation also can be used to determine reservoir operation strategies and reservoir storage requirements (Mays & Tung, 1992). Simulations are conducted by trial and error for reservoir release. Some indicators to assess the reservoir operation performance can include reliability, resilience, and vulnerability. The basic equation of the simulation process is developed from the continuity equation. The constrain of the reservoir system can be formulated as shown in equation 1 to 4 (Mays and Tung, 1992; Rachmad Jayadi, 2012):

Without release

$$R_t = 0; \text{ } if\ S_t + I_t - E_t \leqslant DS \quad (10)$$

Fail release

$$R_t = S_t + I_t - E_t - DS; \text{ } if\ DS < S_t + I_t - E_t \leqslant DS + TR_t \quad (11)$$

Meet the target release

$$R_t = TR_t; \text{ } if\ DS + TR_t < S_t + I_t - E_t \leqslant C + TR_t \quad (12)$$

Overflow condition

$$R_t = S_t + I_t - E_t - C; \text{ } if\ S_t + I_t - E_t > C + TR_t \quad (13)$$

where:

R_t : actual release of reservoir t period (m^3),
TR_t : target release of reservoir t period (m^3),
S_t : storage of reservoir t period (m^3),
I_t : inflow t period (m^3),
E_t : daily evaporation t period (mm)
DS : minimum storage (m^3),
C : Capacity of reservoir (m^3).

2.8. Flowchart Research

Data analysis and research stages were conducted in accordance with the research flow are shown in Figure 7.

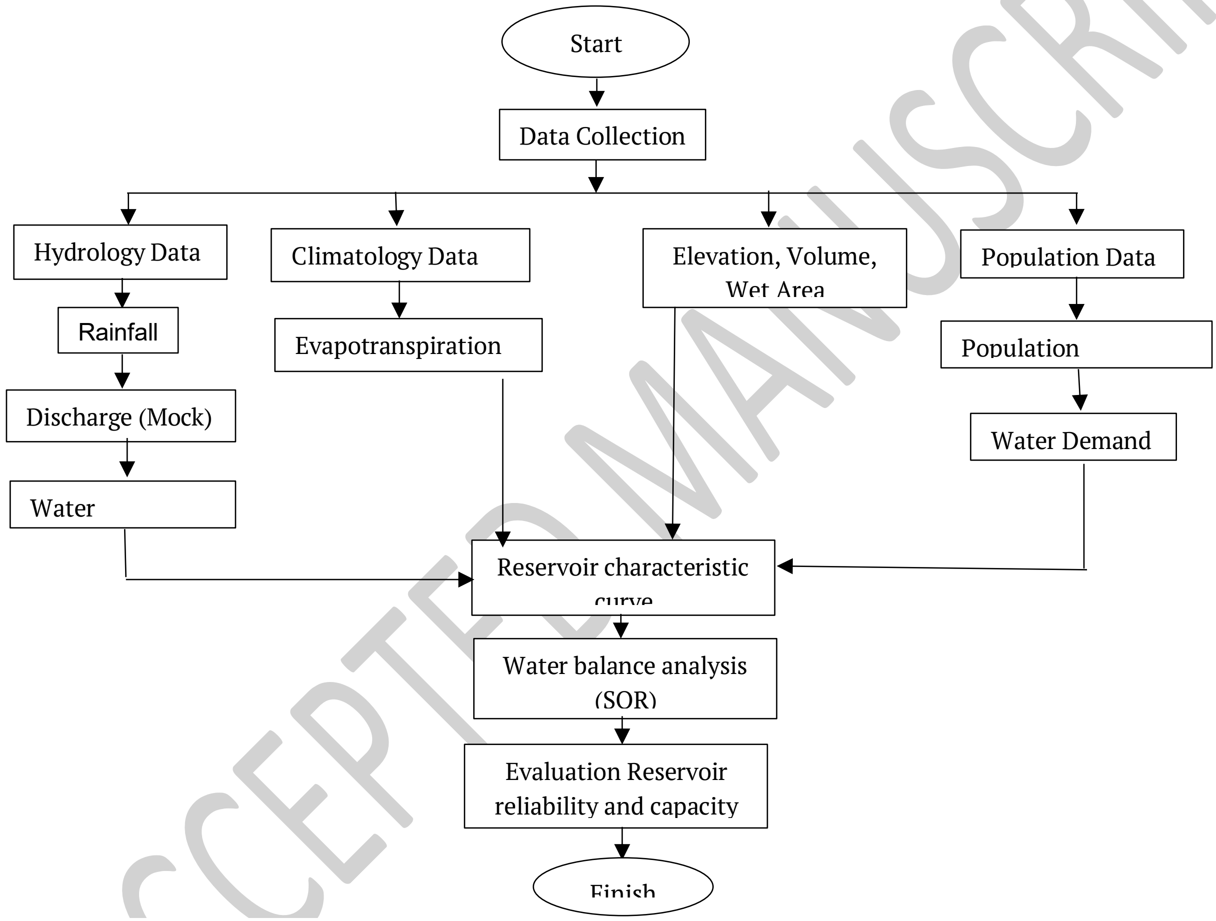

Figure 7. Research flow

3. RESULT

3.1. Water balance

The comparison between water demand and availability in the city of Dili shows that the increase in water demand from year to year is not accompanied by the availability of water in the Comoro watershed. Deficits occur for the next 10 years. Water sources in the Comoro watershed are declared unable to meet the water needs in Dili. The results of the water balance analysis can be seen in Table 3 and Figure 7

Table 3. Water demand and availability

Year	Water demand (m^3/sec)	Water availability (m^3/sec)
2015	0.613	0.328
2016	0.617	0.328
2017	0.625	0.328
2018	0.633	0.328
2019	0.641	0.328
2020	0.684	0.328
2025	0.775	0.328
2030	0.968	0.328

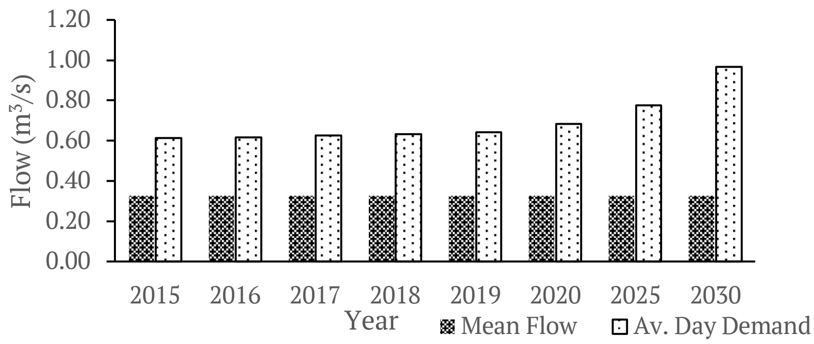

Figure 8. Water Balance Dili

To increase water availability, surface water sources in the Comoro watershed need to be improved. This will also reduce the exploitation of groundwater. The development of water resources in the Comoro watershed through the construction of reservoirs that aim to accommodate river water that has a small discharge. In this study, develop 2 scenarios of reservoir simulation. The simulation of reservoir potential will be divided into:

1) Develop 2 small reservoirs and simulate the reliability based on the inflow and capacity of the reservoir. The first reservoir is the Beemos reservoir, which is assumed to serve 60% of the water demand. The second reservoir is Becora reservoir to serve 40% of the water demand.
2) Develop a large volume reservoir, the Beemos reservoir, and simulate the inflow-outflow and the appropriate reservoir capacity to serve 100% of the water demand.

3.1. The small reservoir simulation

The target release of a small reservoir is for urban demand. The elevation of the reservoir is defined from the data DEM and the maximum and minimum storage capacity of both small reservoirs are obtained from equation 6 and 7. While the total wetted area is calculated using equations 8 and 9. The Beemos reservoir will be developed to serve 60% of demand. The small Becora reservoir will be developed to serve 40% of city needs. The technical data of 2 small reservoirs are showing in Table 4.

Table 4. Technical data of small reservoir

Data	Beemos	Becora
Maximum elevation	+210 m	+186 m
Minimum elevation	+194.50 m	+172 m
Total depth	15 m	15 m

Elevation of Spillway	+207.5 m	184 m
Maximum capacity	0.480 MCM	0.110 MCM
Minimum capacity	0.0058 MCM	0.0043 MCM

The input to the simulation of reservoir reliability is the future inflow, net demand, and evaporation. The future inflow has resulted from the algorithm method of Thomas and Fiering. The potential release of the reservoir will depend on the inflow, storage volume, and evaporation. The target release of the reservoir depends on the net demand. The reservoir will have good reliability if the reservoir can release all the water to achieve the target.

The reservoir simulation to determine the reliability is obtained using the constrain equation 1 to 4. The results of Beemos small reservoir simulation as shown in Table 5 and Figure 8

Table 5. The reliability of Beemos reservoir

Year	Inflow (MCM)	Outflow (MCM)	Overflow (MCM)	Reliability (%)
2021	1.179	0.391	0.788	
2022	1.120	0.552	0.607	
2023	1.137	0.412	0.686	
2024	1.075	0.502	0.573	
2025	1.216	0.542	0.674	
2026	1.200	0.610	0.589	69.17 %
2027	1.282	0.626	0.656	
2028	1.282	0.559	0.722	
2029	1.264	0.672	0.591	
2030	1.694	0.911	0.784	
Average	1.245	0.541	0.654	

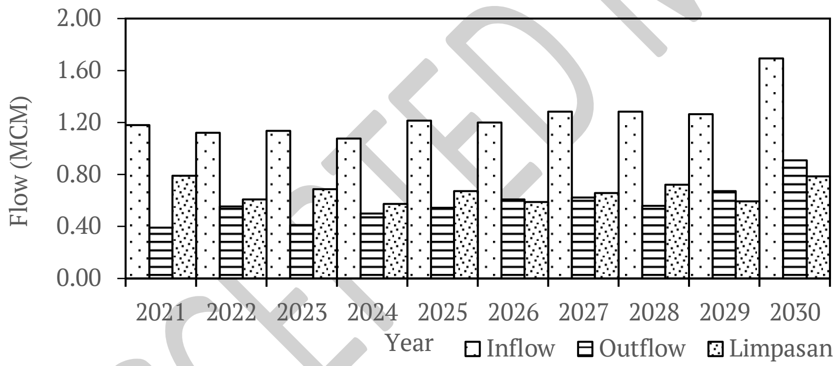

Figure 9. Beemos small reservoir Inflow-Outflow

Based on the simulation results of the reliability of the Beemos reservoir in 2021 to 2030 shows that the Beemos reservoir has a reliability of 69.17%. This means that the volume of water reservoirs from the Beemos reservoir is only 69% able to meet 60% of urban water needs from 2021 to 2030. The reliability does not reach 100% because not every month of the year can reach the target release. The total average monthly inflows are 1.245 MCM. The total monthly average of actual release (outflow) is 0.541 MCM. The average monthly overflow that occurs is 0.645 MCM. The results of Becora's small reservoir simulation as shown in Table 6 and Figure 9

Table 6. The reliability of Becora reservoir

Year	Inflow (MCM)	Outflow (MCM)	Spill (MCM)	Reliability (%)
2021	0.991	0.348	0.643	
2022	0.863	0.319	0.543	
2023	0.599	0.265	0.334	
2024	0.769	0.267	0.502	
2025	0.712	0.331	0.381	52 %
2026	0.633	0.261	0.372	
2027	0.672	0.304	0.368	
2028	0.555	0.281	0.273	
2029	0.861	0.360	0.501	
2030	0.693	0.373	0.319	
Average	0.735	0.311	0.424	

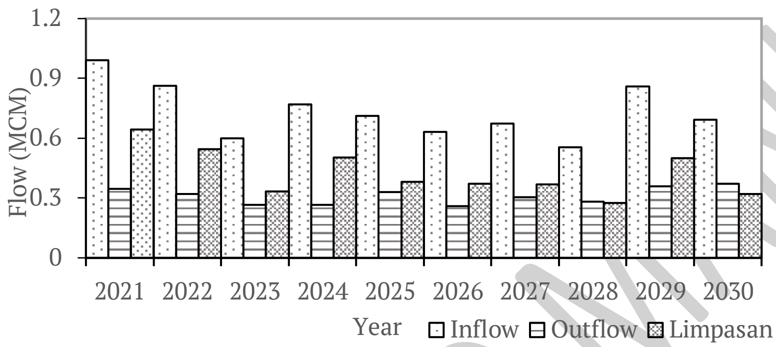

Figure 10. Becora small reservoir Inflow-Outflow

Based on the simulation results of the Becora reservoir reliability, the Becora river inflow is smaller than the Beemos river. Therefore, in planning, the Becora reservoir will be designed with a small volume to serve only 40% of city demand. The simulation results showed that the total average monthly inflow of the Becora reservoir is 0.735 MCM. The annual average outflow was released to meet the target release is 0.311 MCM. The total monthly average of overflow is 0.424 MCM. The reliability of Becora reservoirs is 52%. This shows that every month the reservoir cannot have 100% good performance to release the water.

3.2. The large reservoir capacity simulation

The small Beemos and Becora reservoir simulation results show that the reservoir is not enough to accommodate the inflow of both rivers. The operation of reservoirs can be done but because of the small volume of the reservoir, it can result in large overflow wasted. Therefore, a larger reservoir is preferring than a small reservoir. The size or volume of a large reservoir certainly affects the cost of construction and operation. However, if the reservoir infrastructure can meet the water needs in the city of Dili and the overflow that occurs can be reduced, it will provide positive benefits. Reservoirs can also be operated for multipurpose.

Simulation to determine reservoir capacity needs to be done before calculating its reliability. Input data in the reservoir capacity simulation are the Beemos river inflow generate data from 2021 to 2030 and Dili net water demand data. Evaporation data is assume ignored in this simple simulation. Reservoir capacity is given of 20% for the minimum reservoir to accommodate sediment. Due to its large size and cost considerations, it is planned to build 1 reservoir in the Beemos river which has a large enough water discharge. The results of the Beemos reservoir capacity simulation can be seen in Table 7 and Figure 10

Table 7. The Simulation of Beemos large reservoir

Storage Capacity =		7.41	(MCM)
Storage min.volume =		1.5	(MCM)
Years	Inflow (MCM)	Outflow (MCM)	Spill (MCM)
2021	1.179	0.958	0.368
2022	1.120	0.979	0.298
2023	1.137	1.001	0.000
2024	1.075	1.022	0.137
2025	1.216	1.176	0.050
2026	1.200	1.198	0.000
2027	1.282	1.219	0.000
2028	1.282	1.240	0.090
2029	1.264	1.261	0.030
2030	1.694	1.682	0.000
Average	1.245	1.174	0.097

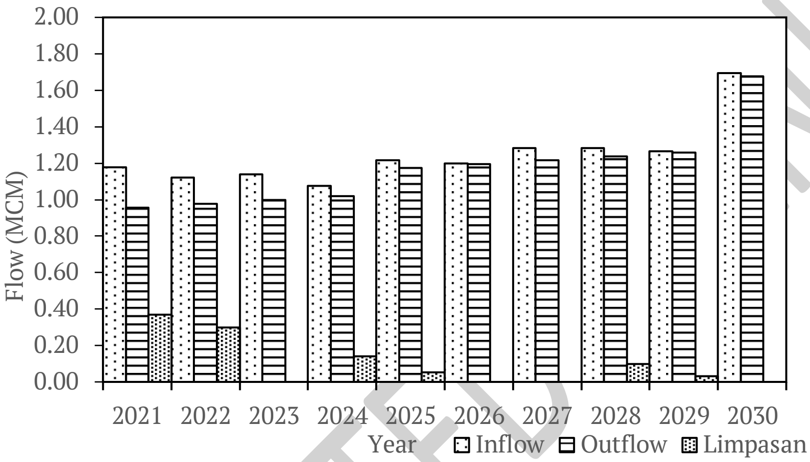

Figure 11. Beemos large reservoir Inflow-Outflow

Based on the simulation of reservoir capacity shows that the Beemos large reservoir capacity is 7.41 MCM. This capacity is greater than the capacity of the Beemos and Becora reservoirs. The capacity of this reservoir to serve 100% of urban needs in Dili, can also be used as flood control and for hydropower. The minimum reservoir volume is 1.5 MCM. The average monthly inflow is 1.245 and the average outflow is 1.174 MCM.

According to the simulation results every year there is still little overflow from the reservoir. The monthly average overflow is 0.097 MCM. This overflow volume is very low compared to the inflow. Inflow can be utilized by 90% while only 10% will spill as an overflow. In Figure 11 can be seen fluctuations in reservoir reservoirs. From August to early November the storage volume declined due to reduced inflow. From the end of November to July the reservoir volume increases. By knowing the monthly storage fluctuations, it can be arranged water release arrangements for urban purposes.

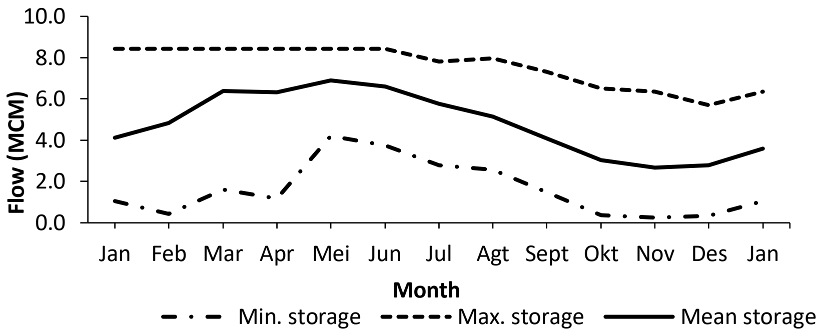

Figure 12. Fluctuation of Beemos storage volume

4. DISCUSSION

The projection of average water demand until 2030 increases by 0.968 m3/sec while the total water availability is 0.328 m3/sec. The results of the water balance analysis show that until 2030, Dili will experience a water deficit. Based on the water balance graph, water availability in the city of Dili tends to consistent until 2030. While the graph of water demand continues to increase until 2030 as the population grows. The assumption of the analysis of the availability of water that consistent until 2030 is with the consideration that there is no strategic plan for the development of water resources in the Comoro watershed until 2018. Development plans in the water sector from 2015-2018 only focus on developing the water supply system in urban and rural areas.

The impact of developing a small dam and reservoirs to meet water needs is not effective. This is due to the small size of the reservoir so cannot accommodate the volume of inflow from the Beemos and Becora rivers. Therefore, the overflow was occurring with a large volume. In the analysis, the target release was not meet by the inflow every month. In the dry season when the inflow has decreased, the reservoir cannot adequate to reach the target. However, the overflow seems like abandon and cannot be utilized in the dry season. Although the overflow happens, it is not significant means that the reliability of the reservoir is 100%. The reliability of two small reservoirs is low until 2030 is because the capacity of the reservoir is small and not adequate to store all volume of inflow therefore in the dry season the reservoir cannot meet the target release. The construction of small reservoirs is implicated less effectively for meeting the urban water needs until 2030.

The large reservoir construction is a required alternative that can be implemented to meet the water demand of Dili by 2030. Large reservoir volumes are possible to accommodate inflow from the Beemos river. The result of overflow that occurs from the large reservoirs is less than that occurs from the small reservoirs. The Inflow of 90% can be utilized, it is expected that the urban water demand can be met.

The construction of reservoirs to meet urban water needs in Dili City is one of the follow-up actions (action plans) for implementing the priority strategy, namely the development of water resources infrastructure. The capacity and reliability simulation results show that the water demand in Dili from 2021 to 2030 can be fulfilled through the construction of the large Beemos Reservoir. Therefore, the implications of developing water resources infrastructure by reservoirs developing show a good indication. Although the simulation results show a good indication, the government still has to carry out a detailed feasibility study related to geological, climatic, hydrological, land use, environmental, and social conditions in the upstream area of the Becora and Beemos before it is implemented.

This indication of the good results of the reservoir development can guide the government to pay attention to other work plans for this priority strategy. Another work plan recommended in the implementation of the priority strategy is a plan to build and improve the distribution system and water availability. This work plan also needs to be implemented so that it can support the function and operation of the reservoir development. Thus, if the clean water distribution system has a good performance, the function of the reservoir will also provide great benefits for fulfilling urban water demand until 2030.

5. CONCLUSION

Based on the simulation of the Beemos and Becora reservoir operations carried out for 10 years (forecast) from 2021 to 2030, the reliability of the Beemos reservoir in release water will be reached 69% and Becora reservoirs reached 52%. Both of small reservoir will not meet the Dili urban demand until 2030 due to the low reliability that below of 100%. The simulation of the capacity of the large Beemos reservoir shows that the reservoir capacity can accommodated and reduce the overflow. The inflow can effectively utilize. Therefore, the large reservoir will be able meet the water demand until 2030. Furthermore, the implementation of the water resource management strategy through the construction of the Beemos reservoir and dam should be considered by the Timor Leste government regarding to develop the surface water source to meet the water demand in Dili until 2030. In this study, there are still some gaps that need to be examined further. The reliability of the large Beemos reservoir with multipurpose functions should be carried out in the future study. Direct measurement of flow in the Beemos river is highly recommended so can produce accurate inflow discharge values in the analysis of the Beemos large reservoir reliability.

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