IMPACT OF CLIMATE CHANGE ON THREE LARGE RESERVOIRS OPERATION IN CITARUM RIVER – INDONESIA

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1. INTRODUCTION

Citarum River with a length of ± 270 km has an upstream area that is mostly located in Bandung regency and partly in Garut regency. Citarum River flows from the south then moves towards the West which then turns to the North with the largest estuary in MuaraBendera - Java Sea. The Citarum River area which is the working area of Jasa Tirta II Public Corporation consists not only of the Citarum River basin, but is a unified hydrological system that combines the Citarum River and its surrounding rivers, the result of water resources development based on the thought of Blommestein (1949).

On the Citarum River there are three stair-shaped reservoirs (cascade) with a classification of large dams, namely Saguling, Cirata, and Jatiluhur. These three reservoirs are managed by different institutions, namely Saguling by Saguling Power Generating Unit (UBP) under PT Indonesia Power, Cirata by UBP Cirata under PT PJB where PT Indonesia Power and PT PJB is a subsidiary of PT PLN (Persero) while Jatiluhur is in the management of Public Company (Perum) JasaTirta II (PJT-II) under the management control of State Minister of State-Owned Enterprises with related technical department is Ministry of Public Works.

The water resources in the Citarum river is the main source of raw water supply other than the surrounding rivers that are integrated in the Jatiluhur infrastructure system for various purposes, including the need for raw water for drinking water of DKI Jakarta and the district / municipal water supply companies, raw water for industry, irrigation area of 240,000 ha, flood control, hydroelectricity and others. The Citarum cascade reservoir has an installed generation capacity of ± 2000 MW with an annual production of ± 3.7 TWh (3.7 x 109 kWh).

Climate change is already a fact. The doubling of CO2 emissions (ppm) compared with the Industrial Revolution in the 19th century is defined as a half degree of world temperature rise. This will lead to an increase in half the degree of global warming for decades to come, due to the inertia of the climate system (Javornik, 2008). The growing awareness of the environment is transformed in the form of global pressure on the use of renewable and environmentally friendly energy sources. Hydropower as one of the environmentally friendly energy sources has an important role in facing the world policy in climate change. On the contrary, hydropower has a dependence on water availability conditions both spatial and time in optimizing its generation, which in this case refers to the operation of the reservoir.

2. CONFIGURATION AND POTENTIAL WATER RESOURCES

The Citarumcascade reservoir operation cannot be separated from the Citarum River Basin system as a whole because the Citarum River has become a hydrological entity through the development of natural resources based on the Blommestein thought that unites the natural resource potential of the Ciujung River (Banten Province) to Kali Rambut (Pemali) (van Blommestein, 1949). This rationale is realized in the development of Citarum River through Jatiluhur Multipurpose Project with the construction of Jatiluhur dam and dam along with irrigation infrastructure so that the Citarum River with the surrounding rivers, from Ciliwung River to Cilalanang River into one hydrological unit as "Figure 1".

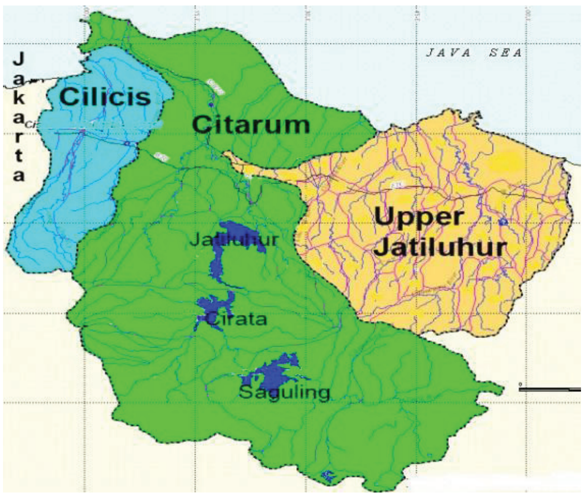

Figure 1 : The Citarum River Basin with the surrounding rivers and part of the Ciliwung-Cisadane River Region becomes a hydrological unit.

Extensive infrastructure development with the objective of meeting the water requirement for irrigation of 240,000 ha in the northern plains of West Java as the fulfillment of national food, raw water supply especially for DKI Jakarta in addition to the Regency / Municipal PDAM and industry, electricity generation, fishery, and etc. The development of natural resources in the Citarum River is done by optimizing the availability of water from the surrounding rivers, namely Ciliwung, Bekasi, Cikarang, Ciasem, Cigadung, Cipunegara, and Cilalanangas "Figure.2 ".Citarum cascade reservoir consisting of Saguling, Cirata, and Ir. H. Djuanda became the main source of supply to meet various water needs downstream of Ir. H. Djuanda dam.

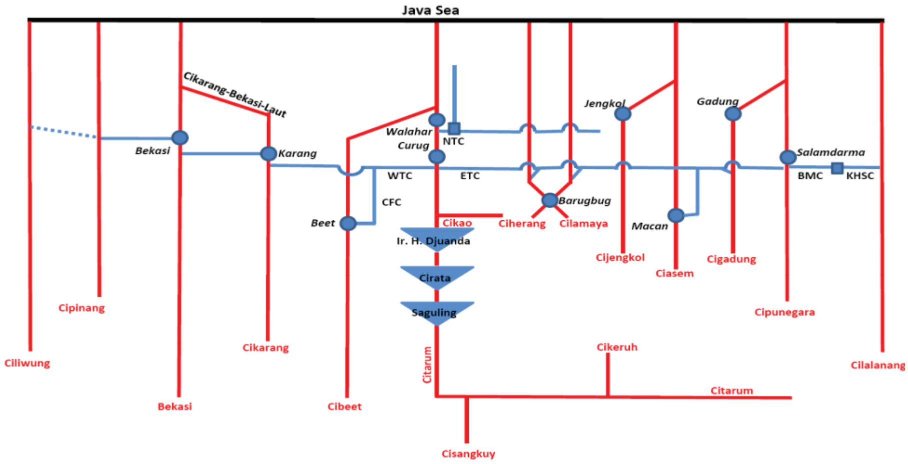

Figure 2 : Schematic development of water resources in the Citarum River Basin through optimization of water sources from rivers around the Citarum River

The potential of natural resources in WS Citarum can be distinguished into: [1] natural resource potential of Citarum River which is managed through Citarum cascade reservoir operation and,[2] optimization of local water sources through the operation of weirs. With the existence of the three reservoirs in the Citarum River, almost all the potential of natural resources in the CitarumRiver of 6.0 x 109 m3 can be used to meet various downstream needs as a byproduct of electricity generation, because the main priority of Citarum cascade reservoir operation is for the fulfillment the need for water downstream of the Jatiluhur dam. With no reservoirs for local water sources, the potential of natural resources of 6.95 x 109 m3 can only be used for 1.65 x 109 m3. The biggest beneficiary is for irrigation by 87% of the total manageable water as "Figure.3".

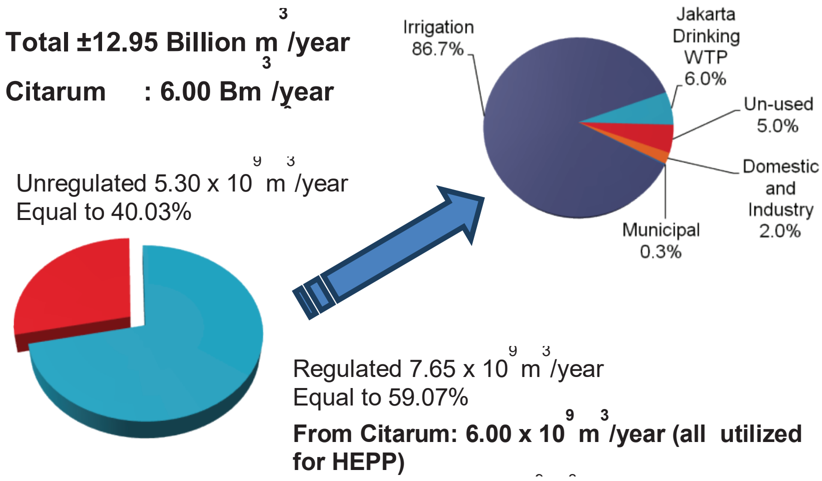

Figure 3 : Configuration of potential and utilization of water resources in Citarum River Basin

3. THE CITARUM RIVER HYDROLOGICAL REGIME.

Indonesia in the tropics in general the main characteristics of the tropical climate is the uniformity of temperature, solar radiation, humidity, wind speed. While the main climate parameter that varies in time and space is rainfall. Factors that control rainfall are (van der Weert, 1994): equatorial double rainy seasons, transfers (monsoons), and local influences. Presents regional variations of rainfall in Indonesia. It is generally seen that seasonal variations are highly visible in Java, Nusa Tenggara, East Timor, and South and Southeast Sulawesi.

Annual runoff depends on rainfall and evapotranspiration. In general, the evapotranspiration in the catchment area is relatively small compared to the existing rainfall, so it is not surprising that the annual rainfall is closely related to runoff (van der Weert, 1994). The runoff component is divided into base flow, interflow and surface runoff. Determination of surface flows for irrigated agricultural areas, mixed gardens, settlements, and plantations is a correlation between soil types, slope and slope length as well as flow management practices.

Citarum River is one of the rivers that have long discharge data. In 1922, the discharge post was installed in Palumbon which was in the upper reaches of Jatiluhur reservoir with an area of 4133 km2 of DAS. In January 1944, during the period of independence war, observation data were interrupted and resumed from May 1962 to August 1987 when the station was dismantled because of the flooding of the Cirata dam construction.

Based on the recording of all long-term data in the Citarum River basin using Isohyet method, the mean annual rainfall is estimated to be 2610 mm. From the comparison of precipitation in the pre-independence period (Sep-22 to Aug-29) with after independence (Sep-79 to Aug-86) the annual rainfall is almost 2454 mm / year and 2470 mm / year but the annual flow is increased by 10% from 1137 mm / year to 1261 mm / year (van der Weert, 1994).

In addition, from the observation data of debit at the Palumbon station fluctuations of flow debits between the period before independence (1923-1943) and after independence (1963-1984) were higher. Based on the Citarum cascade reservoir operation data, there is a decrease in annual flow and also higher fluctuations as “Figure.4”. Changes from this hydrological regime could be attributed to land use change. Unfortunately, there are no statistics on land use data prior to the independence war that can be used as a comparison. Changes in the hydrological regime include the tendency of seasonal leap, longer dry season, shorter rain time with greater intensity as an indication of climate change as “Figure 5”.

Under such conditions, at the operational level of the Citarum cascade reservoir the question arises, “How to treat the reservoir reservoir and Citarum cascade reservoir operation to anticipate the trends?”

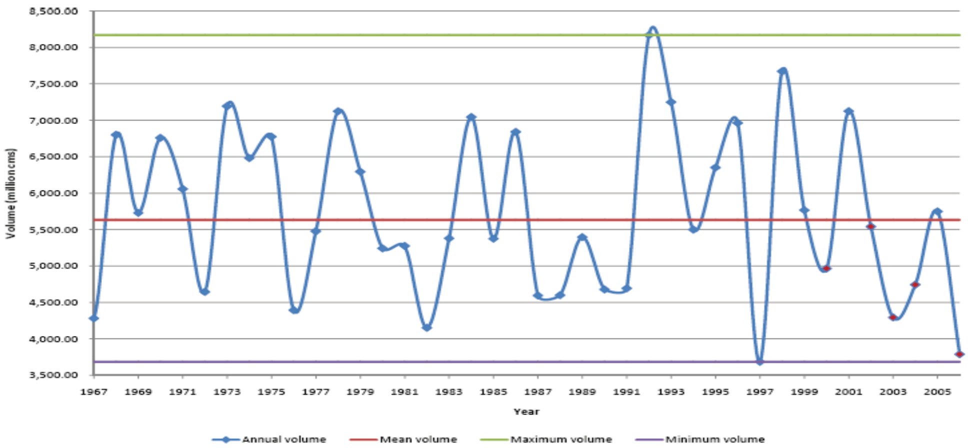

Figure 4 : The annual volume of Citarum during the year 1967-2006.

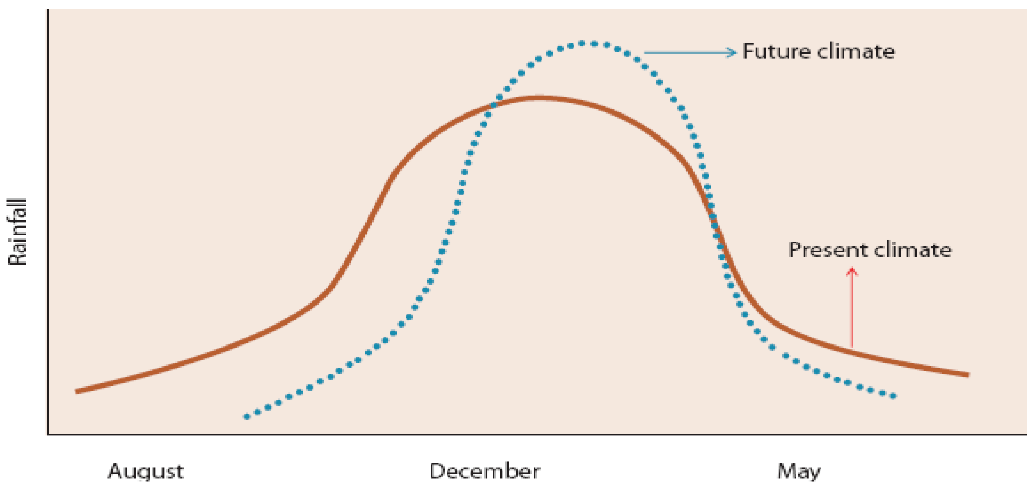

Figure 5 : Trend of rainfall pattern in Java and Bali (source: UNDP Indonesia, 2007)

4. ADAPTATION OF OPERATION PATTERN OF CITARUM CASCADE RESERVOIR

4.1 Operation of Citarum Cascade Reservoir.

The Citarum cascade reservoir has a net capacity of 2.0 x 109 m3, where the net catch is determined from the elevation of the spillway and the minimum elevation of the reservoir (at the Jatiluhur reservoir minimum hydro operation). With annual flow of Citarum in Jatiluhur at ± 5.75 x 109 m3 equivalent to 49% of net capacity, it indicates that this Citarum cascade reservoir is not designed to provide reserve reserves under long drought conditions. The technical data on the Citarum cascade reservoir is presented in as “Table 1”.

Table 1 : Technical Data of Citarum Cascade Reservoir

Name of Dam	Saguling	Cirata	Ir. H. Djuanda
Operational	1985	1988	1967
Specific Reservoirs Data			
Full supply level	643 m	220 m	107 m
Dead storage level	623 m	205 m	56 m*)
Minimum power level	-	-	75 m
Maximum storage	880 x 10^6 m^3	1,973 x 10^6 m^3	2,970 x 10^6 m^3
Minimum storage	271 x 10^6 m^3	1,177 x 10^6 m^3	599 x 10^6 m^3 **)
Surface area at max operating level	49 km^2	62 km^2	83 km^2***)
Hydropower Plant Data			
Tail level (m)	252	103	27.0
Head loss (m)	28.4	4.0	1.0
Spillway characteristics	Gated spillway	Gated spillway	Ungated (ogee) spillway
Installed capacity (max. power, MW)	750	1008	187.5
Number of turbines	4 units	8 units	6 units
Type of turbines	Francis	Francis	Francis
Dam Data			
Type	Rockfill dam with clay core	Rockfill dam with concrete face	Rockfill dam with inclined clay core
Height	99 m	125 m	105
Crest length	301 m	453.5 m	1220 m
Crest elevation	650.20 m	225.0 m	114.5 m

Note: *) Based on the existing layout of guiding canal in front of hollow jet gates. **) at El. 49 msl **) at El. 107 msl.

The annual operation of this Citarum cascade is made by estimating the water requirement, the statistical data of inflows to the three reservoirs with the total energy generated by the system optimized with priority based on the fulfillment of water requirements downstream of the Ir. H. Djuanda Dam. Water needs downstream of the Ir. H. Djuanda reservoir is primarily for the fulfillment of raw water supply of daily necessities (raw water of DKI Jakarta and districts / cities), irrigation, industry and others.

The water requirement downstream of the Ir. H. Djuanda reservoir is mainly for irrigation covering almost 87% of the total water requirement. Therefore, to determine the water requirement required the classification of irrigation water supply for Jatiluhur Irrigation Area of 240,000 ha by considering data of water availability from local sources, channel capacity and plan and condition of existing cropping pattern. The data is traced from the furthest irrigation area to the water requirement at BendungCurug as the main building for the various needs downstream of the Ir. H. Djuanda dam by considering also the water loss in the channel and the safety factor.Water needs downstream of the Jatiluhur dam became one of the inputs in establishing the Citarum cascade reservoir operation. Some of the principles (limits) in determining the operation of the Citarum cascade reservoir are as follows:

- Runoff is avoided.
- Water level elevation at the end of the year is equal to or more than the water level at the beginning of the year.
- The principle of equal-sharing operation, ie the proportion of clean reserves for each reservoir against the total system is constant, ie 18.8% for Saguling, 24.4% for Cirata and 56.8% for Ir. H. Djuanda.

The inflow data for the three reservoirs was statistically determined using data from 1988, the year from which the Citarum cascade reservoir system began to operate fully. From the input data, optimization is done so that the maximum power production with the water requirement is fulfilled with the optimization process done by the Solver program.

In operating the model, the reservoir operation model is conducted sequentially and needs to be continually updated and re-operated to obtain the most accurate forecast data on real conditions and how operational decisions are established for each component of the operation of the reservoir. With many interested parties in the operation of this Citarum cascade reservoir, the Citarum cascade operation is always evaluated and updated monthly through a coordination meeting mechanism within the coordinating team for the operation dam cascade of the Saguling, Cirata and Ir H. Djuanda.

4.2 Economic Value of Water on Citarum Cascade Reservoir Operation.

Climate change is one of the risk factors in the sustainability of the reservoir operation so it should be managed as well as possible through the deepening of climate change and its impact on reservoir operation and management of natural resources as a whole. Climate change, which can lead to changes to the hydrological regime in this case decreasing annual flow may result in a decrease in the production of hydropower generation.

It has also been realized that the day the economic value of water is increasing, and water is not only seen as a social good as it is mentioned in the principle of integrated natural resources management (GWP TAC, 2000). The management of natural resources (= Citarum cascade reservoir operation) is very unique considering the history of Jatiluhur reservoir management is based on the idealism to apply self-reliance in the management of natural resources as a whole, where the utilization of natural resources (water, water and water resources) can be used to fulfill the operational and maintenance of natural resources infrastructure although very limited.

More specifically, the equivalence of the amount of water for power generation for each hydropower unit is affected by the installed capacity and the falling height, $P = f(Q, H)$ with $Q = f(H)$. So for PLTA Saguling, Cirata, and Jatiluhur have their own characteristics of the economic value of water in the generation of electricity. Given the impacts of climate change that require the adaptation of reservoir operations to mitigate the impact, which has little impact on the economic value of hydropower generation, this should also be considered in the Citarum cascade reservoir operation as part of integrated natural resource management.

4.3 Alternative Adaptation and Optimization of Citarum Caskade Reservoir Operation.

The water reservoir in the reservoir contributes about 30% of the world's water availability. If the irregularities caused by climate change that affect the hydrological regime continue to increase, then access to water is decreasing which causes the higher levels of water shortage in the world (Berga, 2008). Adaptation to climate change in the form of initiatives and treatments aimed at reducing human and natural vulnerability in the face of the effects of climate change.

There are several potential handling that can be done, ie in the form of pure technology (eg infrastructure, storage, sea water defense, etc.), behavioral management (water conservation, productivity and water efficiency, changes in food and tourism patterns), management Integrated natural resources, alternative farming practices) to policy (eg, regulatory planning). In the SDA sector, this adaptation strategy can include adding water catchments to rainwater harvesting, conservation, water reuse, irrigation water efficiency to desalinization. Adaptive capacity is the ability of a system to adapt to climate change (including climate variability and hydrological regime change) to reduce potential damage, to take advantage of existing opportunities or to anticipate the consequences. In reservoirs with large capacity, changes in water availability are relatively smaller compared to systems with no small containers or containers. Therefore, reservoir operations on large systems are becoming stronger to changes in water availability, more resistant to the effects of climate change, and shelter acts as a buffer against climate change.

With the down-scaling, in the case of the Citarum cascade reservoir system where the largest reservoir is in the Jatiluhur reservoir, with a proportion of 56.8% of overall capacity, the capacity of the Citarum cascade reservoir adaptation is in Jatiluhur reservoir. So in the Citarum cascade reservoir operation, Jatiluhur reservoir acts as a buffer against two reservoirs above it. This is contradictory to the principle of operation of reservoirs equal-sharing requiring a balance of clean containment proportions for each constant fixed reservoir and avoiding changes in water level in each reservoir to change drastically from month to month.

Changes in the operating principle of Citarum cascade reservoir will have implications for the economic potential value generated from electricity generation. Therefore, in accordance with the idealism in the management of natural resources in the Citarum River Region unit to achieve independence, the economic value of water must be accommodated in the Citarum cascade reservoir operation. At the present stage, the adaptation of Citarum's cascade reservoir operation to reduce the impact of climate change is done by optimizing the capacity of the container to hold water in the wet season as much as possible in the dry season but by providing space for flood control.

In addition to water availability adaptation, adaptation of water needs through on-demand irrigation management and improved rainwater catchment conditions to improve retention capacity as well as efforts to hold water forever in the area upstream activities such as increasing capacity through the construction of water catchments to rainwater harvesting and water reuse.

5. CONCLUSION

Climate change is a world problem and one way to reduce the impact of climate change is by using renewable energy sources, such as hydropower. On the contrary, with the influence of climate change, especially on hydrological regimes that are closely linked in reservoir operations, the operation of the reservoir needs to be strengthened by considering these conditions in its operations to reduce its impact. Climate change must be understood as one of the business risks that can result in the decline in electricity production. This should also be considered in terms of operation and management of reservoirs.

The hydrological regime in the Citarum River is changing, as indicated by the higher flow rate fluctuation and the higher coefficient of run-off and the indication of seasonal leap, the longer the dry season, the shorter rain time with the greater intensity requires that adaptation of Citarum cascade reservoir operation to mitigate the impacts of climate change, by optimizing the capacity of containers to hold water in the wet season as much as possible for the needs in the dry season but by providing space for flood control.

The greatest capacity of Ir. H. Djuanda dam reservoirs is the value of adaptation capacity in the Citarum cascade reservoir operation so that in the Citarum cascade reservoir operation, Ir. H. Djuanda reservoir acts as a buffer against two reservoirs above it. Adaptation of water demand through on-demand irrigation management and improved rainwater catchment conditions to increase retention capacity as well as efforts to hold water forever in upstream areas such as increasing capacity through the construction of water catchments up to rainwater harvesting and water reuse.

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