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Analysis of Reservoir Water Storage and Management in the SIER Industrial Zone

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Abstract. *This study analyzes the water storage capacity and operational patterns of reservoirs in the Surabaya Industrial Estate Rungkut (SIER) to support efficient and sustainable water resource management. The research adopts a quantitative approach by collecting hydrological data, analyzing storage capacity, and simulating reservoir operations based on seasonal scenarios. The findings indicate that SIER's reservoirs have sufficient capacity to meet industrial water demands, although a supply deficit occurs for four months annually. Technical optimization efforts, such as sediment dredging, have proven to increase storage capacity by more than 200%. Practical recommendations for reservoir management include sedimentation normalization and planned operational strategies. These findings are expected to serve as a reference for other industrial zones in addressing water management challenges due to climate variability and increasing industrial demands.*

Keywords *Operational Patterns, Seasonal Scenarios, Supply Deficit, Climate Variability*

1. INTRODUCTION

The Surabaya Industrial Estate Rungkut (SIER) is one of Indonesia's leading industrial areas, playing a strategic role in supporting national economic development. With various industrial activities taking place, the need for an adequate and sustainable water supply is a key factor in ensuring the continuous operation of this area. A stable water supply is not only essential for production activities but also for supporting domestic needs and environmental sanitation within the industrial estate.

However, the challenges in water resource management have become increasingly complex, especially with unpredictable climatic fluctuations, such as extreme rainy seasons and prolonged droughts. In addressing these conditions, reservoirs play a crucial role as a source of raw water supply and as a flood control mechanism. The reservoirs in the SIER area are designed to accommodate specific water demand capacities; however, their effectiveness depends on optimal management and well-planned operational strategies.

Research on water storage capacity and reservoir operational patterns is highly relevant to ensure efficient water resource management. By understanding the actual storage capacity of the reservoirs and how their operational patterns are designed, industrial areas can mitigate the risk of water shortages during droughts and reduce flood risks during rainy seasons.

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Moreover, effective reservoir management can alleviate environmental burdens and enhance the sustainability of industries in the area.

This study aims to analyze the storage capacity of reservoirs in the SIER industrial area and evaluate their operational patterns. The methods employed include hydrological data collection, topographic analysis, and operational pattern simulations based on seasonal scenarios. The findings of this research are expected to provide recommendations for more effective water resource management while contributing to the development of a sustainable industrial area.

Through this research, insights will be provided on how the current reservoir capacity can meet industrial water demands and how operational patterns can be optimized to maintain a balance between operational needs and environmental sustainability. This study can also serve as a reference for reservoir management in other industrial areas across Indonesia.

2. METHODS

This research employs a quantitative approach, utilizing primary and secondary data systematically analyzed through three main stages:

1. Data Collection

The first stage involves collecting data on rainfall, topography, and hydrology within the SIER industrial area. Rainfall data is gathered from local meteorological stations and used to study annual rainfall patterns and seasonal variations. These patterns are crucial for estimating the availability of water during rainy and dry seasons. Topographic data is obtained through field surveys or digital maps, providing information on the morphological characteristics of the land, such as elevation and slope around the reservoir. This data is essential for determining the catchment area contributing to the reservoir's water supply. Hydrological data, including inflow and outflow rates of the reservoir, is collected to understand the dynamics of water flow and the temporal storage capacity of the reservoir.

2. Storage Capacity Analysis

Once the data is collected, the analysis of reservoir storage capacity is conducted using the volumetric method. This involves calculating the water volume the reservoir can store based on topographic data and reservoir depth. The process includes creating a three-dimensional model of the reservoir to determine its maximum capacity. This analysis also evaluates the effective capacity of the reservoir, which is the optimal storage capacity that can be utilized without compromising its flood control function. The results of this stage provide crucial information on the reservoir's potential to meet water demands in the industrial area.

3. Reservoir Operational Simulation

The final stage involves simulating reservoir operations using hydrological simulation software. The simulation incorporates data on rainfall, inflow and outflow rates, as well as environmental factors such as evapotranspiration levels. The aim is to model the operational patterns of the reservoir under various conditions, such as high-intensity rainy seasons and limited water supply during dry seasons. The simulation results reveal how the reservoir can be managed to balance water demand and mitigate the risks of flooding or drought. Additionally, the simulation evaluates the effectiveness of operational strategies implemented during the observation period.

Each stage complements the others to provide a comprehensive understanding of the storage capacity and operational patterns of reservoirs in the SIER industrial area. This approach aims to offer practical recommendations to enhance reservoir management efficiency.

3. RESULTS

The results section summarizes the data collected for the study using descriptive statistics and reports the outcomes of relevant inferential statistical analyses (e.g., hypothesis tests) conducted on the data. Report the results in sufficient detail so that the reader can understand which statistical analyses were performed, why they were conducted, and to justify your conclusions. Mention all relevant results, including those that contradict the stated hypotheses.

There is no fixed formula for presenting the findings of a study. Therefore, we will first consider general guidelines and then focus on options for reporting descriptive statistics and the results of hypothesis tests.

Present your findings as concisely as possible while providing enough detail to justify your conclusions and enable the reader to understand exactly what you did in terms of data analysis and why. Figures and tables, detached from the main body of the manuscript, often allow for clear and concise presentation of findings.

4. DISCUSSION

3.1 Hydrological analysis

For the subsequent analysis, the Log Pearson Type III method is used for the design rainfall analysis. The design rainfall values are as follows:

- R_1 = 48.50 mm
- R_2 = 78.21 mm
- R_5 = 97.75 mm
- R_{10} = 111.11 mm
- R_{20} = 122.42 mm
- R_{25} = 128.50 mm
- R_{50} = 141.88 mm
- R_{100} = 155.61 mm
- R_{200} = 169.91 mm
- R_{1000}= 205.35 mm

To determine the design flood discharge, the Rational Method is used. This method is chosen because the watershed area (DAS) is less than 50 km². The value of C is taken as 0.80–0.90, based on Schwab et al. (1981) and Arsyad (2006), as the area is an industrial zone. The flood discharge calculated using the Rational Method (Madayu) is as follows:

- Q_2 = 2.87 m^3/dt
- Q_5 = 3.58 m^3/dt
- Q_{10} = 4.07 m^3/dt
- Q_{20} = 4.49 m^3/dt
- Q_{25} = 4.71 m^3/dt
- Q_{50} = 5.20 m^3/dt
- Q_{100} = 5.71 m^3/dt
- Q_{200} = 6.23 m^3/dt
- Q_{1000} = 7.53 m^3/dt

For water availability analysis calculations using the FJ Mock method. In accordance with PP River No. 38 of 2011, the water requirement for river maintenance flow protection is carried out by controlling the availability of 95% (ninety five percent) of the mainstay discharge. Current state of Water Balance Study (2024):

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- In terms of quantity, the SIER Reservoir has the potential to be used for raw water needs with a discharge reliability of Q90%.
- Happen Deficit availability water for 4 months, namely in the months: July - August - September - October.
- Based on Regulation Government of the Republic of Indonesia No. 38 of 2011 Concerning Rivers, Article 25 (3), For protection flow maintenance Reservoir must leaving water in reservoir as much as 6,397.19 m^3.
- So the Safe Limit for Water Withdrawal Per Month (SURPLUS Period: January to June, and November and December) = 121,546.52 m^3 = 46.89 lt / sec.
- Safe Limits for Water Withdrawal (CRITICAL/DEFICIENT Period) = 25,588.74 m^3 = 9.87 lt /sec
- For Increasing the Safe Limit Value for Water Withdrawal, Technical Optimization Efforts are Needed in the form of Normalization Dredging Sediment Reservoir.

Water balance study after normalization:

- Happen Deficit availability water for 4 months, namely in the months: July - August - September - October.
- Based on Regulation Government of the Republic of Indonesia No. 38 of 2011 Concerning Rivers, Article 25 (3), For protection flow maintenance Reservoir must leaving water in reservoir as much as 12,966.18 m^3.
- So the Safe Limit for Water Withdrawal Per Month (SURPLUS Period: January to June, and November and December)

= 246,357.38 m^3

= 95.05 lt /sec.

- Safe Limits for Water Withdrawal (CRITICAL/DEFICIENT Period)

= 51,864.71 m^3

= 20.01 lt /sec

- Technical Optimization Efforts with Normalization Dredging Sediment Reservoir capable raise less water usage more than 200% of condition latest 2024.

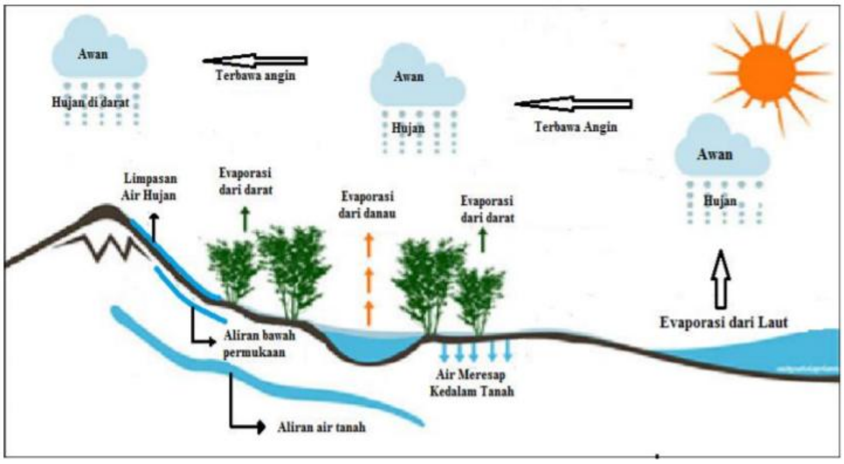

Figure 3.1 The Hydrological Cycle

(Source: Triatmodjo, 2016)

3.2 Bathymetry Measurement Evaluation Results

1. The results of the capacity curve analysis from bathymetry measurement data obtained a total volume of 6 reservoirs currently (2024) of 131,382.85 m ^{3} .
2. In a period of 32 years (from 1992 to 2024) the SIER Reservoir experienced sediment deposition of 131,382.85 m ^{3} , so that the Sediment Rate was 4,271.17 m ^{3} /year or 11.86 m ^{3} /day.

3.3 Reliability reservoir in accommodate *runoff* area

1. The SIER area is divided into 6 Runoff Zones , where:

- Zones 1 and 2 covering an area of 206.62 Ha are included in the SIER Reservoir ,
- Zone 3 covering an area of 19.63 Ha enters Channel 25-26,
- Zones 4, 5 and 6 covering an area of 93.14 Ha enter the river Tambakoso ,
- Administratively Zones 1, 2 and 3 are in the city of Surabaya, while Zones 4, 5 and 5 are in the district of Surabaya. Sidoarjo,

2. Reliability in accommodate or reduce debit flood Runoff in the SIER area , *as* following :

- For debit overflow of Zone 1, Zone 2 amounting to 1.31 ^{m3} / sec which enters the SIER Reservoir with potential total volume of space guard The SIER reservoir is 229,651.93 m ^{3} , so The SIER Reservoir <u>CAPABLE</u> accommodate debit Runoff for 48.85 hours or ±2.04 days
- For debit Zone 3 runoff of 0.06 m3 $^/$ sec which enters Primary Channel 25-25 with potential volume capacity channel full without sediment (*bankfull) capacity*) Channel 25 - 26 is 10,229.60 m ^{3} , then Channels 25 – 26 <u>CAPABLE</u> accommodate debit Runoff for 47.54 hours or ±1.98 days . Where recommended in the form of Effort Physical /

Structure Normalization (BQ = 2,046 m^3) and Water Gate for Regulation from Channel 25-26 leads to the River Tambakoso .

3.4 Plan budget cost

The normalization process of sediment dredging in six reservoirs within the Surabaya Industrial Estate Rungkut (SIER) requires a substantial budget allocation amounting to Rp. 10,412,026,000.00 (Ten Billion Four Hundred Twelve Million Twenty Six Thousand Rupiah). This budget is deemed necessary to address the significant sedimentation issues that have accumulated over a period of 32 years, which has reduced the reservoirs' effective capacity to meet industrial water demands. The sediment dredging aims to restore the reservoirs' storage capacity, improve water flow, and enhance the reservoirs' ability to manage runoff effectively during both surplus and deficit periods. By increasing the water withdrawal safety limits and reducing the risk of floods and droughts, this effort plays a critical role in ensuring the sustainability of water resources for industrial operations. Furthermore, the planned normalization aligns with the broader goals of optimizing water resource management, mitigating environmental challenges, and supporting the industrial sector's resilience to climate variability. Through this significant investment, it is expected that the operational patterns of the reservoirs will be improved, providing long-term benefits for the SIER area and serving as a model for similar industrial zones in Indonesia.

5. CONCLUSION

This study analyzes the water storage capacity and operational patterns of reservoirs in the Surabaya Industrial Estate Rungkut (SIER) to support efficient and sustainable water resource management. The results show that the reservoirs in SIER are sufficient to meet industrial water demands, although a supply deficit occurs for four months each year. Technical optimization efforts, such as sediment dredging, have proven to increase storage capacity by more than 200%.

Practical recommendations include sedimentation normalization and planned operational strategies to mitigate the risks of drought and flooding caused by climate variability and increasing industrial demands. This study is expected to serve as a reference for other industrial areas in addressing water management challenges, thereby supporting the development of sustainable industrial zones.

6. FUNDING

This research was conducted without financial support from external institutions, whether governmental, private, or nonprofit organizations. All costs related to the research activities, including data collection, analysis, report writing, and publication, were entirely borne by the authors. Thus, this research is independent and not influenced by the interests or agendas of any third parties. The authors hope that the results of this study will contribute significantly to the advancement of knowledge and serve as a valuable reference for those in need.

7. CONFLICTS OF INTEREST

This research was conducted without financial support from external institutions, whether governmental, private, or nonprofit organizations. All costs related to the research activities, including data collection, analysis, report writing, and publication, were entirely borne by the authors. Thus, this research is independent and not influenced by the interests or agendas

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