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SUSTAINABLE WATER PROVISION MODEL FOR MOROWALI INDUSTRIAL AREA: A SYSTEM DYNAMICS MODEL

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Abstract

This study aims to investigate the availability of clean water in KI Morowali through a dynamic system analysis, considering the key strategic area's (Morowali Industrial Area, MIA) role in providing water for industrial and residential purposes. By 2026, the traditional water sources are expected to fall short of meeting the increasing demands from both sectors. To address this challenge, the study proposes integrating regional water supply sources, dam utilization, and promoting green open spaces (GOS) within the industrial park area. The method utilized involves analyzing the relationships between various variables impacting water availability. The results highlight the potential for significantly improving MIP's water supply by optimizing catchment zones, increasing GOS in private areas, and adopting a holistic approach to sustainable water management. This comprehensive strategy aims to ensure resilient water resources for Morowali's future needs, mitigating water scarcity challenges effectively.

Keywords: Morowali, water supply, industrial park, nickel, system dynamics

Introduction

The mining industry employs millions of people and serves as a key contributor to Indonesia's economic growth. According to sector growth forecasts, Indonesia's mining industry is poised for continued expansion. Based on data from the CRIF, the industry is projected to grow by 4.34% in 2023 compared to 2022. Additionally, the Indonesian government actively promotes the growth of the mining industry through investment and regulation. Two significant regulations, Government Regulation Number 15 of 2022 concerning Mineral and Coal Mining and Law Number 3 of 2020 concerning Minerals and Coal Mining, have been released to support industry development. To attract investment, the government has also introduced initiatives such as the Mining Product Export Incentive (IEPP) and Indonesia Mining Week (IMW). Despite the mining industry's immense potential in terms of natural resources, mining companies face increasing challenges (Ranto et al., 2023). Stringent regulations, global environmental shifts, and societal demands for sustainability all play a role. Notably, Indonesia grapples with a major problem: providing water for its industrial parks. Indonesia's mining industry stands at a critical juncture, balancing growth aspirations with responsible practices and addressing pressing water availability concerns.

The Morowali Industrial Park (MIA), located in Morowali Regency, Central Sulawesi, holds a prominent position as one of Indonesia's National Strategic Projects (PSN) and a priority target for infrastructure development by the Ministry of Public Works and Housing (PUPR). Under the oversight of PT Indonesia Morowali Industrial Park (IMIP), MIA's primary potential lies in the processing of ferronickel and stainless

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steel, along with downstream products. MIA's strategic position in Central Sulawesi contributes to its economic significance. The primary potential of this region, which is overseen by PT Indonesia Morowali Industrial Park (IMIP), is in the processing of ferronickel and stainless steel, as well as the products that come after. In general, several variables, such as Morowali Industrial Park's geographic location, industry demands, the state of the infrastructure, and governmental regulations, affect the availability of water. One of the Indonesian regions in Central Sulawesi with significant economic potential is Morowali, particularly in the mining and industrial sectors. Water demands in industrial parks and zones are high for a variety of reasons. However conventional water supply techniques frequently find it difficult to keep up with the growing demand, which results in inefficiencies and disruptions that impede growth and productivity. A few major obstacles that traditional water supply systems must overcome such as inadequate capacities, unreliable supply, high cost, and environmental impact. To support industrial parks with sustainable efforts, this study will first model the water demand balance for industrial parks and then develop water supply scenarios.

Water resources are heavily utilized worldwide, and meeting the world's growing water demand is becoming more difficult due to population growth and climate change (Okello et al., 2015). A comprehensive water system management plan must be created by resolving several complex and interconnected problems (Bello et al., 2019). The majority of research on industrial water supply primarily considers how to maintain the water balance. Some of these researchers such as Thuy et al. (2016) and Jiang et al. (2019) discuss various sources of water for the industrial Ishak (n.d.), discuss how to provide raw water supply for the Morowali industrial park. Furthermore, from the fulfillment of the regional water supply, a more thorough examination of the water supply system is required (Hou et al., 2021). To accomplish this, techniques that can model these systems and produce an approximative assessment of reality in addition to system analysis are required (Kloprogge et al., 2011). Dynamic system science provides the solution to this requirement. It is particularly challenging to comprehend the possible effects of decisions due to the intricate relationships and dynamic feedback between the technical and environmental systems (Kotir et al., 2016). A valid scientific foundation for enforcing management strategies is dynamic simulation and modeling of diverse water resources in real-time (Kotir et al., 2016). This method's advantages include the capacity to enhance a group or series of models more quickly, the ability to modify and correct simple models in response to system changes, and others. In academic society, there is a high scientific and application liability associated with the study of dynamic systems (Karnopp et al., 2012). Among the widely used techniques for system analysis, objective dynamic modeling based on feedback is a straightforward and efficient approach that defines the system without the need for intricate mathematical components. This approach has been widely used in recent decades to model a wide range of water resource management issues (Koushali et al., 2015).

Morowali Industrial Park (MIP) (Figure 1) is located in Bahodopi Sub-district, Morowali Regency, Central Sulawesi Province at coordinates 2°49'15.4 "LS 122°09'31.1 "BT. MIP is one of 14 industrial estates prioritized in the 2020-2024 Indonesia National Medium-Term Development Plan (RPJMN). The park is directed as a nickel processing industry with supporting infrastructure and facilities. Morowali Industrial Park, managed by PT Indonesia Morowali Industrial Park (IMIP), is an integrated nickel-based industrial park and home for around seventeen tenants. Industry is one of the sectors supporting the economy of Central Sulawesi Province and Eastern Indonesia. In 2022, the manufacturing industry in Central Sulawesi contributed 2.93 percent of the country's GDP and 43.61 percent of the KTI GDP of the manufacturing industry. The high potential availability of nickel natural resources in Central Sulawesi shows the high contribution of the processing industry, especially the mining processing sector, and its production reached 18 million tons.

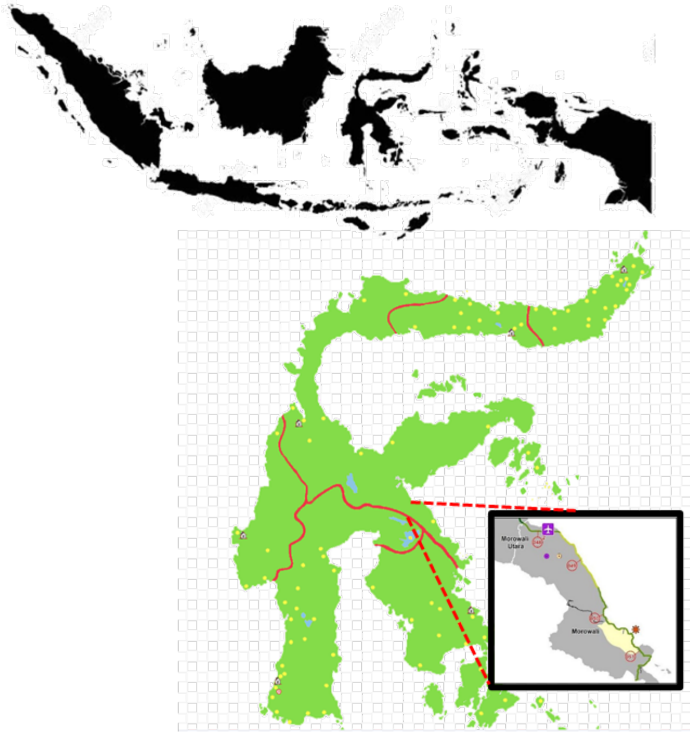


Figure 1. Study Area Morowali Industrial Area

Moreover, this study aims to investigate the availability of clean water in KI Morowali through a dynamic system analysis, considering the key strategic area's (Morowali Industrial Area, MIA) role in providing water for industrial and residential purposes

Research Method

This research aims to build a model of sustainable water provision in the Morowali industrial park. IMIP's raw water requirement is calculated using reliable river discharge using national water standards (Ishak, n.d.). System dynamics is used to understand the behavior generated by the existing structure and the implications of scenarios that arise when a policy is intervened in the existing structure. This model is used to study complex, dynamic, nonlinear systems through feedback management. The system built emphasizes the structure and behavior of a system formed by interacting feedback (Jin et al., 2016). The system Dynamics method is suitable to use for making population projections over time since it implements the feedback loop (Pitoyo et al., 2018). Problem identification and definition, system conceptualization, model formulation, testing and evaluation, model use, implementation, and dissemination, as well as the creation of a learning strategy and infrastructure, are common steps in system dynamics modeling (Figure 2) (Forrester, 1970; Homer, 2019; Soesilo & Karuniasa, 2014). There are no hard boundaries between the phases in this flexible, iterative process, and the modeller may need to go back and revisit earlier iterations to incorporate fresh data or insights. Another crucial component of the procedure is a dynamic hypothesis, which is a theory regarding the structure that produces the reference modes. Furthermore, a "step-by-step" method that incorporates the model evaluation into the model development process has been suggested for the creation of system dynamics models (Pejić-Bach & Čerić, 2007).

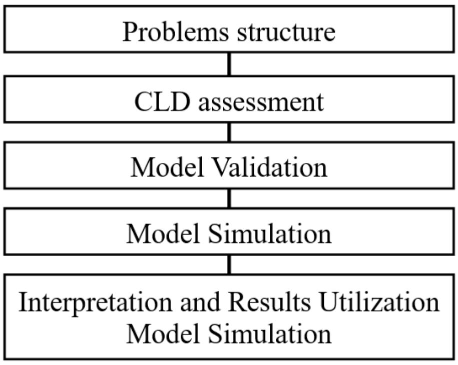


Figure 2. System Dynamics Method
Source: (Forrester, 1969), (Soesilo & Karuniasa, 2014)

Population Analysis

Population projections in this system are influenced not only by birth and death rates but also by outgoing and incoming migration rates (Figure 3). Migration rates are very important in this area because it is predicted that there will be 77,000 workers who will enter the Morowali industrial area. Population figures greatly affect the demand for clean water for domestic use. The population data was gathered from national census data in 2020 as the base year. Domestic water consumption is the multiplication of population and individual standard water consumption (120 litre/person) (Saputra et al., 2020).

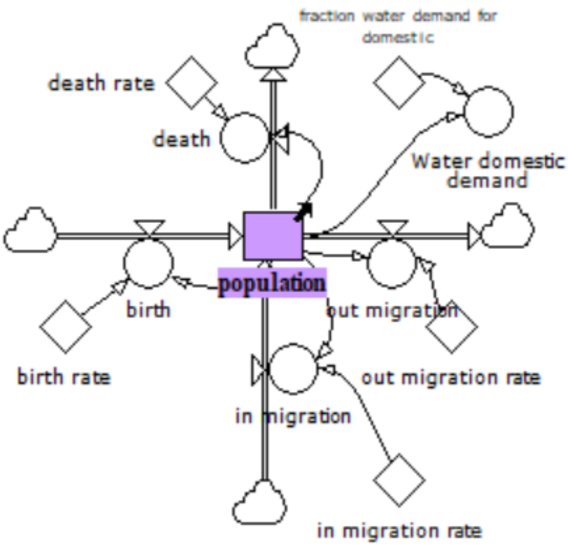


Figure 3. Morowali Population Model

Water Consumption

The water consumption (WC) model in the industrial area is an aggregate of water supply for domestic, industrial, and service activities. It aggregates water supply for domestic, industrial, and service activities within MIA. Components of water consumption including Domestic Water Consumption (DWC) is water essential for meeting the basic needs of the population, including drinking, sanitation, and household use. Industrial water consumption (IWC) is water for industrial processes such as cooling, cleaning, and manufacturing. Facilities Water Consumption (FWC) is water for Public facilities, commercial establishments, and institutions also contribute to water consumption. Loss is estimating water loss due to leaks in distribution systems is crucial for efficient water management. Based on the supply and demand of clean water in the area, a water balance of the Morowali Industrial Park can be obtained.

$$\text{Water Consumption} = DWC + IWC + FWC + \text{loss} \quad (1)$$

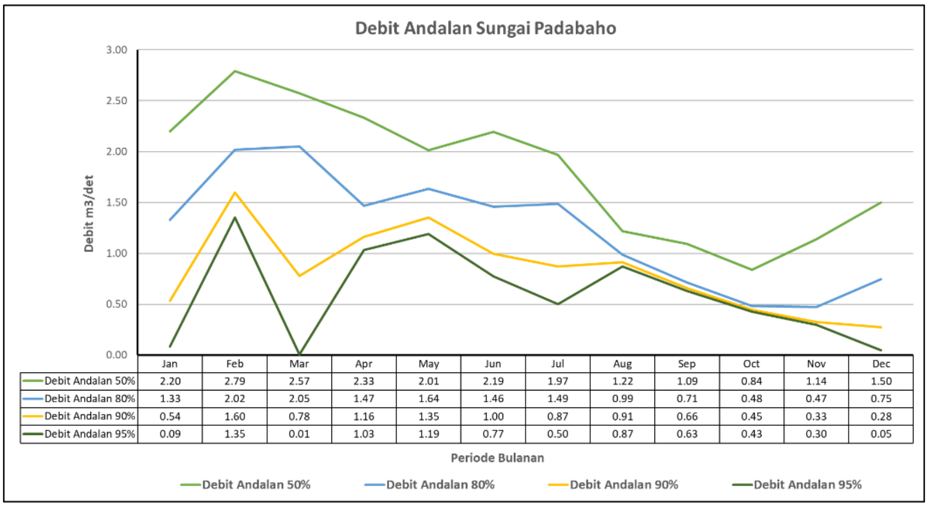
Where DWC is domestic water consumption (liter), IWC is industrial water consumption (liter), and FWC is facilities water consumption (liter). with a total municipal and industrial household water demand (RKI/WC) of $6{,}52 \times 10^{13}$ liter/year. The growth rate (G) indicates changes in average demand derived from data from Central Sulawesi province's clean water statistics.

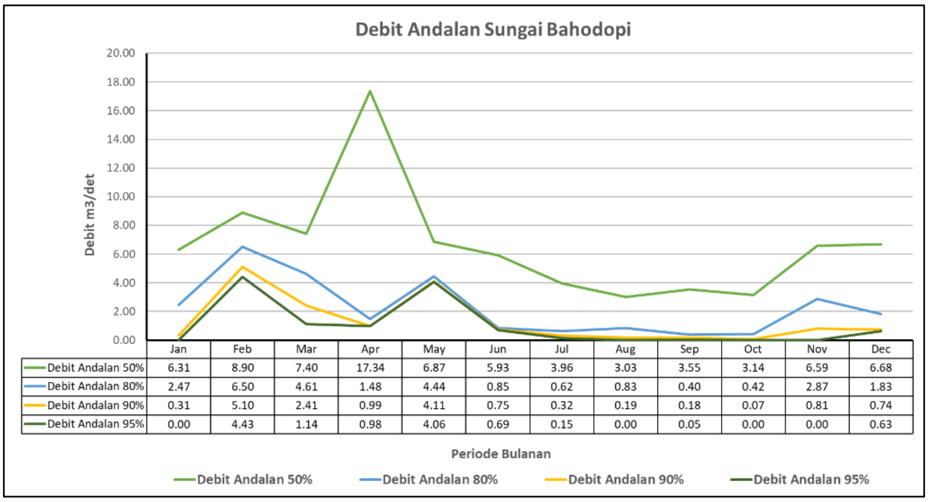
Water Supply

Conventionally, water sources for industrial areas are obtained through three sources: rivers, springs, and groundwater. One important effort in maintaining the sustainability of water sources in this area is to maintain the water catchment area by increasing green open space, and retention. Based on water consumption, and water supply, the water balance for Morowali Industrial Park is built.

IMIP's raw water needs are planned to be supplied from the Bahodopi River and Padabaho River (Figure 4) with a total availability of 8,12 m^3/second, therefore if the appropriate raw water supply infrastructure is offered, it can be considered sufficient.

Figure 4 displays the monthly change in Sungai Padabaho's minimum discharge. Four lines on the graph, 50%, 80%, 90%, and 95%, stand for various percentages of minimum discharge. According to the graph, minimum discharge at 50% reaches its maximum peak in February, while at 95% it nearly disappears for the entire year. In addition, the graph displays percentages and numerical values for each month. The monthly change in Sungai Bahodopi's minimum discharge at 50% has the highest peak in April and May, while Debit Andalan at 95% is almost zero throughout the year. The graph also has numerical values for each month and percentile.





	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Debit Andalan 50%	6.31	8.90	7.40	17.34	6.87	5.93	3.96	3.03	3.55	3.14	6.59	6.68
Debit Andalan 80%	2.47	6.50	4.61	1.48	4.44	0.85	0.62	0.83	0.40	0.42	2.87	1.83
Debit Andalan 90%	0.31	5.10	2.41	0.99	4.11	0.75	0.32	0.19	0.18	0.07	0.81	0.74
Debit Andalan 95%	0.00	4.43	1.14	0.98	4.06	0.69	0.15	0.00	0.05	0.00	0.00	0.63

Figure 4. The Primary Discharge of Pabadaho and Bahodopi River

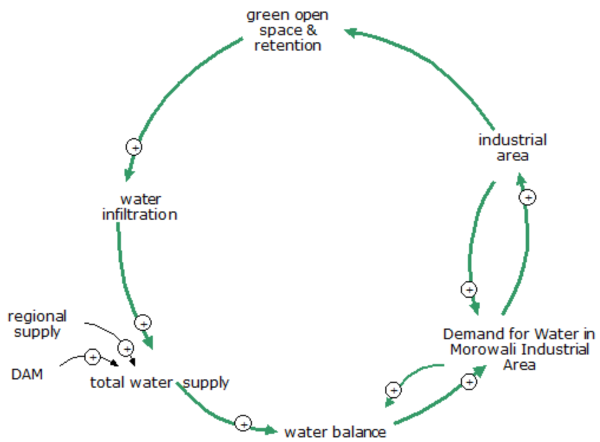


Figure 5. Causal Loop Diagram Sustainable Water Provision for Morowali Industrial Area

The system dynamics model in the analysis process uses PowerSim software. Building an understanding of the system dynamics model in general, according to Koushali et al. (2015), has several stages, namely defining the problem in the field, determining significant variables to the system, determining mathematical equation that can describe the behavior of the system, and determining the period of the simulation. Determining variables that describe the behavior of a system can be done using several criteria:

1. These factors are imperative and altogether impact framework behavior. This depends on the limitations made by modelers, components exterior of the framework are considered not critical and are not taken under consideration in making the demonstration.
2. Comparative variables must be combined since a couple of variables will maintain a strategic distance from pointless complexity.
3. Factors must be accurately characterized.

Figure 5 is a Causal Loop Diagram (CLD) illustrating the water supply and demand cycle in an industrial area, specifically the Morowali Industrial Area. It shows how water is sourced, supplied, and balanced within this environment. The diagram outlines the process from DAM to regional supply, total water supply, and water balance. It also highlights the role of green open spaces and retention industrial areas in influencing water infiltration and demand. It shows the importance of managing water resources in an industrial area, where water is needed for various purposes. The diagram also shows the potential challenges and trade-offs involved in ensuring a sustainable water cycle, such as the impact of industrial activities on water quality and quantity, the competition between different water users, and the effects of climate change on water availability and variability. The diagram suggests some possible solutions or strategies to optimize the water cycle, such as increasing the water efficiency and reuse in the industrial area, enhancing the water storage and retention capacity of the green open spaces, and balancing the water supply and demand through appropriate allocation and regulation mechanisms. The diagram can be used to model the water cycle, such as the industrial operators, the local authorities, the water service providers, and the surrounding communities. It can also be used as a basis for further analysis and evaluation of the water cycle performance and impacts.

The framework flow strategy should generalize the design of behavior of the framework in casuistic after modelers can decide the variable. The system's behavior must be caught on in causal relationship/feedback circles that will shape a framework structure. The framework flow is comprised of a fundamental show (commerce as usual/BAU) and a demonstration with a scenario. The fundamental show of framework elements could be a framework that happens nowadays without any arrangement mediation being executed. The framework elements recreation employments three scenarios:

1. The BAU scenario is the current framework;
2. The situation of increasing green open space and retention in the area;
3. The use of water from regional water resources and the dam facilitates water collection scenarios.

The Morowali industrial area gets its water supply from springs and groundwater in addition to the river. The Central Sulawesi River Center provided data indicating that the Morowali area could utilize approximately 155 liters of groundwater annually. The growth rate (G) data indicates changes in average supply derived from Central Sulawesi province's clean water statistics.

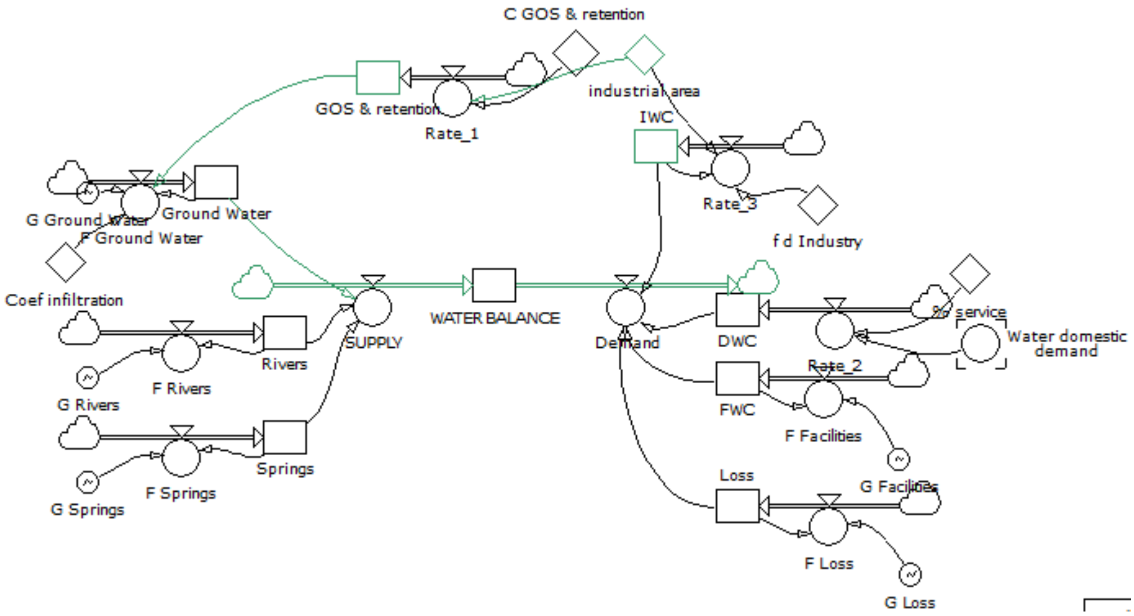


Figure 6. Stock and Flow Diagram Sustainable of Water Provision for Morowali Industrial Area

Results and Discussions

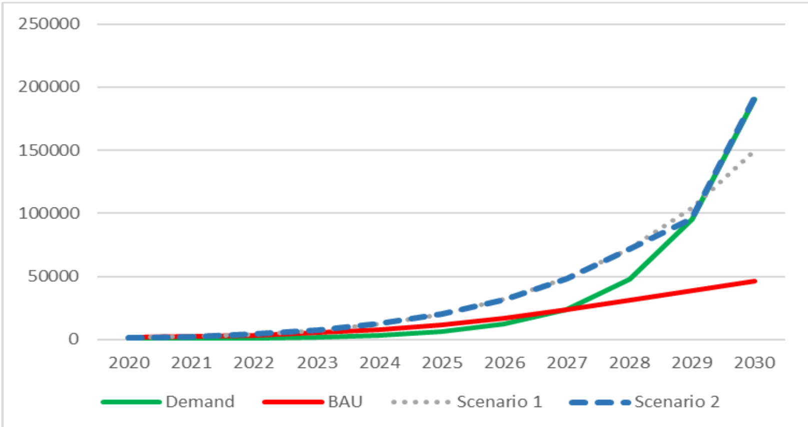


Figure 7. Supply and Demand Water BAU Scenario

The graphic displays a graph of the anticipated demand, under various conditions, for a specific good or service from 2020 to 2030. The graph offers some intriguing observations and suggestions for this market's future. First, the graph indicates that there is little expectation of a significant change in the market conditions and strategies used today over the next ten years, given the near-identical nature of the demand and business-as-usual (BAU) scenarios. This may indicate that there is little space for expansion or innovation in the market since it is established, steady, and saturated.

The following conclusions were drawn from the Morowali industrial area's water supply model simulation results. The water demand for the industrial area is predicted to surpass the water supply from rivers and current springs in 2026 under the business-as-usual (BAU) scenario. In the first scenario where the utilization of green space and retention in the industrial area is 10% under the guidelines for fulfilling green areas, the water demand for industrial areas can significantly increase. However, in the final year of planning 2029, this water supply does not meet the water needs of both the industrial area and its residents, so additional water is needed from other water sources. In the second scenario, water is added to the conventional water supply at the end of the planning year from additional sources, specifically dams, and regions. so that 41 thousand liters per year are required from outside sources. This factor can be utilized because the model shows that the area's provision of GOS and retention can yield a significant amount of additional water.

Conclusions

The availability of water, particularly in the quantity and quality of KI Morowali and its environment, is critical to the sustainability of the nickel processing sector. Morowali Industrial Estate, one of the national priority industrial areas, requires 6.52×10^{13} liters of raw water annually for surrounding residential and industrial uses. Seawater, groundwater, and surface water (the Bahodopi and Padabaho rivers) can all be used to supply raw water. The population of KI Morowali, which includes both locals and immigrants who work there and establish families there, has an impact on the demand for raw water. According to the System Dynamics Method study's findings, there won't be enough water in 2026 to meet household and industrial demands under a "business as usual" scenario. As a result, infrastructure interventions are required, such as the planning of the development of green open space that will serve as a water catchment area and occupy 10% of the entire Morowali Industrial Estate. Building dams to improve water storage as a raw water source is an additional option. Additional measures to ensure the water provision sustainability for Morowali Industria Area must incorporate sustainable development, which is based on three pillars: the economic, social, and environmental. The environmental factor is where the water absorption effort will be at its best if there is at least 10% of the industrial area covered by green space. The development of water resources infrastructure can be made more affordable by optimizing the infiltration area (economic aspect). In terms of the social component, the local government must monitor the green space area to ensure that it makes up at least 10% of the entire Morowali industrial area. Also considered in this study is the number of immigrants who live and work in Morowali industrial as a new social generation.

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