Analysis of Adequacy and Reliability of SPAM Infrastructure based on Water Demand Projections in Simalungun Regency

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Abstract

The availability of adequate clean water is one of the basic needs of the community and an important indicator of the quality of public services. This study aims to analyze the adequacy and reliability of the SPAM system in Simalungun Regency based on infrastructure capacity and projected future water needs. The research uses a descriptive qualitative approach, with primary data obtained through in-depth interviews with SPAM managers, local government officials, and service user communities, as well as secondary data from official documents and related technical reports. The results of the study show that the current capacity of SPAM is nominally able to meet the clean water needs of people in urban areas, but there is a gap in services in some rural areas and new settlements. The level of system reliability is influenced by supply continuity, distribution efficiency, and water source reserves, where network leakage and uneven distribution are the main obstacles. Other factors that affect include water source capacity, distribution infrastructure conditions, operational management, as well as population growth and water demand patterns. Based on these findings, a sustainable SPAM development strategy is needed, including increasing water source capacity, expanding and improving distribution networks, strengthening operational management, planning based on projected needs, and community involvement in water management. The implementation of this strategy is expected to increase the adequacy, reliability, and sustainability of SPAM services in Simalungun Regency, both now and in the future.

Keywords: SPAM, clean water adequacy, system reliability, water demand projection, sustainability, Simalungun Regency

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Introduction

Clean water is one of the basic human needs that is very important to support health, social life, and economic development. The availability of sufficient and quality water is the main indicator of the success of the development of sanitation infrastructure and public services in an area. In Indonesia, the provision of drinking water through the Drinking Water Supply System (SPAM) is one of the priority programs of local governments to ensure that all people have access to clean water that is safe and suitable for consumption. Simalungun Regency, as one of the areas with rapid population growth and economic activity, faces challenges in meeting the needs of clean water for all its people. Increasing population growth, urbanization, and expansion of economic activities are putting pressure on the capacity and reliability of existing SPAM infrastructure. In addition, changes in weather patterns and the availability of raw water sources also affect the availability of water supply. If not anticipated, the mismatch between the capacity of SPAM and the needs of the community can cause various problems, such as disruption of supply continuity, declining service quality, and uneven distribution of clean water.

A number of recent studies emphasize the importance of proper planning and projection of water needs to ensure the adequacy and reliability of SPAM infrastructure. According to Prasetyo et al. (2021), planning based on projected water needs helps local governments in optimizing the capacity of the distribution network, estimating the necessary investments, and preventing future supply shortages. Meanwhile, Hidayat and Wulandari (2022) emphasized that the reliability analysis of the SPAM system is key to ensuring the continuity of water services, especially in areas with rapid population growth.

Table 1. Quantitative and administrative data from PDAM Tirtalihou and the Central Statistics Agency of Simalungun Regency

Indicators/Variables	Grades/Information
Area of Simalungun Regency	± 4,372.5 km² (Simalungun Regency)
Population (mid 2024 estimate)	± 1,051,845 people (Simalungun Regency)
Population density (2023)	± 237 people/km² (One Data Simalungun Portal)
Number of households / households (2023)	258,980 households (One Data Simalungun Portal)
Home connection client (SPAM connection) — RT/KK connection (2024)	38,646 connections (One Data Simalungun Portal)
SPAM service coverage (connection to total household ratio)	~ 13.80 % (2024) (One Data Simalungun Portal)
Installed capacity of SPAM (registered)	575 L/sec (Portal Satu Data Simalungun)
Actual measurable capacity/correction of SPAM	440 L/sec (Simalungun One Data Portal)
Number of SPAM installation units	32 units (One Data Simalungun Portal)
Number of raw water sources used by SPAM	51 water sources (One Data Simalungun Portal)
Annual production of SPAM water	10,341,102 m³/year (One Data Simalungun Portal)
Volume of water sold / SPAM distribution (per year)	6,343,722 m³/year (Simalungun One Data Portal)
Performance Indicator: NRW (NonRevenue Water / water lost/leaky / not collected)	36.7% (2024) (Simalungun One Data Portal)

Indicators/Variables	Grades/Information
Demographic structure (age group) — composition of productive age and children	Productive age (15–59 years) ~ 66.76%; children 0–14 years ~ 20.52% of the total population (2024) (Databoks)
Population composition (2022 data) — total 1,021,615 people, with an average household member ~ 3.93 people/household (One Data Simalungun Portal)	

From the number of residents and the number of households/Heads of Families (KK), you can estimate the minimum water needs based on water consumption standards per capita/per household. This helps the projection of water needs in the present and future. "Service coverage" data (13.80%) shows that only a small fraction of the total households in Simalungun currently have a SPAM connection — this indicates the potential lack of access for many residents. The installed capacity of SPAM vs actual capacity (575 L/s vs 440 L/s) and the NRW figure of ~ 36.7% can be used to show the reliability and efficiency of water distribution issues — water loss, leakage, uneven distribution, etc. Annual production and distribution volumes give an idea of how much water supply is available vs. how much is actually delivered — it can be analyzed whether the current volume is sufficient if the coverage of services is extended (e.g. to 100% households). Demographic structures (productive age vs. children vs. elderly) are relevant for projecting water needs — e.g. needs for sanitation, hygiene, drinking, household activities, new family growth, etc. With current demographic and water supply data, you can create a projected scenario for water demand in the next 5–10 years, especially if population growth according to the CAGR trend (last year) is considered.

In Simalungun Regency, although the local government has built a SPAM network for several sub-districts, there are indications that the availability of water is not enough to meet all the needs of the community. Several community reports indicate supply disruptions, particularly in the dry season, which suggests that SPAM capacity and reliability need to be analyzed more deeply. Thus, this research is important to evaluate the extent to which the existing SPAM infrastructure is able to meet water needs now and in the future, as well as to provide recommendations for the development of more reliable and sustainable systems.

Clean water is a vital basic need for people's lives, health, and economic development. In Simalungun Regency, population growth and urbanization continue to increase, while the coverage of SPAM (Drinking Water Supply System) services is currently only around 13.8% of total households. This condition shows that there is a significant gap between the community's need for clean water and the availability of existing infrastructure. This imbalance not only has the potential to reduce people's quality of life, but also poses serious health and sanitation risks. Therefore, research that focuses on the adequacy and reliability of SPAM is very important to ensure that all communities have access to safe and adequate clean water.

In addition to coverage issues, the capacity and reliability of SPAM are also currently a concern. Data shows that the installed capacity of the SPAM system in Simalungun Regency is 575 L/second, but the measured capacity is only 440 L/second, with Non-Revenue Water (NRW) reaching 36.7%. This condition indicates the potential for water loss, distribution disruptions, and inefficiencies in network management. An in-depth analysis of the adequacy and reliability of SPAM is important so that local governments and PDAMs can plan strategies for developing more optimal systems, reduce water loss, and improve supply continuity for the community.

Projection of water demand is another important aspect. SPAM infrastructure planning that is not based on accurate demand projections risks failing to meet future water demand. Using demographic data, the number of households, and water consumption patterns, this study

can provide an estimate of medium to long-term water needs. The results of this projection will be the basis for strategic decision-making related to network capacity, resource allocation, and the construction of new installation units to improve services.

The common thread of this research lies in efforts to bridge the gap between the availability of SPAM infrastructure and the community's water needs. This study not only assesses the adequacy of current SPAM capacity, but also evaluates the reliability of the distribution system and the continuity of water supply. With an approach based on water demand projection, this research is expected to produce practical and strategic recommendations for local governments in planning sustainable SPAM development. In other words, this research is feasible because it scientifically contributes to the development of data-based clean water planning, as well as practically supporting the improvement of the quality of public services in Simalungun Regency.

In the current literature on pipe/SPAM water supply, many studies focus on the technical aspects of the distribution network, projected water needs, and system sustainability — but almost none combine them all in a single district/broad area-scale study with typical demographic and geographic characteristics. For example, the Analysis of the Drinking Water Supply System (SPAM) in Nambo Village, Lasalimu District, Buton Regency by Aswad Asrasal et al. (2022) projected water needs and designed a piping network for the next 15 years in a village. Their results showed the discharge and configuration of the pipeline that was appropriate for the needs in the village. However, the study was limited to a single village (microregion) with a small population (at the time of the study of 989 people), so the scale was very local and did not take into account aspects of distribution over a large area, geomorphological variations, or larger growth projections.

Similarly, the research on Clean Water Demand Analysis and Performance of Clean Water Distribution Pipelines (Case Study: Banyuurip Branch Water Treatment Plant) by Agung Setiawan, Eko Riyanto & Hari Sakti Nugroho (2024) combined water demand projections with distribution pipeline performance analysis using software so as to approximate the need to evaluate supply-demand suitability. However, the focus remains on one installation/spatial of PDAM services, not the entire district area with many sub-districts and heterogeneous spatial characteristics, such as rural, semiurban, and remote rural areas. This limits the generalization of results and their relevance if applied to a large district such as Simalungun Regency.

Furthermore, the study on the Performance Analysis of the Distribution Pipeline of the Drinking Water Supply System (SPAM) in Kalijering Village, Pituruh District by Muhamad Taufik, Wanda Mafruhul Fithroh & Agung Setiawan (2023) evaluated aspects of water pressure, headloss, and distribution in the pipeline network as an effort to ensure good clean water services. But again, their research was limited to specific villages with relatively small number of home connections so they did not capture the complexity of distribution in different areas, fluctuations in demand, or projected population growth of a large population.

In addition to the technical and distribution aspects, the literature related to the sustainability of SPAM in rural areas also makes an important contribution. For example, A Strategy for Management of Sustainable Water Supply System in Rural Areas by R. Setyaningtyas (2022) reviews the condition of water services in villages after the assistance program (pamsimas), finding that many villages fail to maintain the sustainability of their SPAM, management is not optimal, infrastructure maintenance is inconsistent, and community participation is weak. The study emphasizes the importance of management, institutional, and community participation strategies to maintain long-term water services. However, this study is not equipped with a projection of quantitative water needs, nor an analysis of the distribution and reliability of the pipeline network, so the quantitative technical aspects of adequacy and capacity are often overlooked.

In addition, the need for research like this is increasingly urgent. In the study of Analysis of Clean Water Demand and Clean Water Distribution Performance in Southern Indonesia (2024) — a study by PDAM Banyuurip — although it shows that the current water availability is still able to meet the 2025 projection, the simulation results show that most nodes in the pipeline network have not met the standards of pressure and flow speed. Such findings show that the success of SPAM is not only a matter of volume/discharge but also even distribution, an aspect that must be considered when implementing in districts with diverse geographical conditions such as Simalungun.

Problem Identification

Based on the background and literature review, some of the main problems that arise related to SPAM in Simalungun Regency are:

1. Limitations of SPAM service coverage
   Currently, the coverage of SPAM services in Simalungun Regency has only reached around 13.8% of the total households. This causes most people to still depend on traditional water sources such as wells, rivers, and springs, so that the quality and continuity of clean water supply is not guaranteed.
2. Imbalance between capacity and water demand
   The installed capacity of SPAM is 575 L/second, but the rated capacity is only 440 L/second. In addition, Non-Revenue Water (NRW) reached 36.7%, indicating significant water loss. These conditions indicate potential inefficiencies in distribution and possible supply shortages, especially at peak demand.
3. Lack of analysis of long-term water demand projections
   Many previous studies have only analyzed water needs on a micro scale (village or sub-district) without considering the projection of population and household growth comprehensively at the district level. This poses a risk of SPAM being unprepared to face future needs.
4. Lack of evaluation of the reliability of the SPAM system
   Reliability aspects — such as continuity of supply, distribution efficiency, and water source reserves — have not been thoroughly analyzed in Simalungun Regency. Without this evaluation, the potential for service disruption and the system's inability to cope with critical conditions (drought, network damage) is difficult to anticipate.
5. Variation in geographical and demographic characteristics
   Simalungun Regency has a large area with a combination of rural, semi-urban, and diverse topography. There have been no studies that integrate these characteristics with SPAM capacity and reliability planning, so optimal infrastructure development is still a challenge.

Problem Formulation

Based on the identification of the problem above, the formulation of this research problem is as follows:

1. To what extent is the capacity of SPAM in Simalungun Regency able to meet the community's current clean water needs and future projections?
2. How reliable is the SPAM system in ensuring the continuity of clean water supply, distribution efficiency, and water source reserves?
3. What are the factors that affect the adequacy and reliability of SPAM in Simalungun Regency?
4. What are the recommendations for the SPAM development strategy in order to meet the community's clean water needs in a sustainable manner?

Literature Review

2.1 Employee Engagement

The concept of employee engagement has gained increasing attention in organizational research due to its strong association with performance, retention, and overall organizational success. Kahn (1990) was the first to introduce the concept, defining engagement as "the harnessing of organization members' selves to their work roles," whereby employees express themselves physically, cognitively, and emotionally during role performances. According to Kahn, engagement occurs when employees are psychologically present and personally involved in their work, finding meaning and purpose in their roles.

Employee engagement is influenced by several factors, including leadership style, organizational culture, job design, and psychological resources (Bakker & Demerouti, 2008). Engaged employees demonstrate higher motivation, stronger organizational commitment, and better performance outcomes. In the tourism industry, where service quality and customer satisfaction depend heavily on human interaction, engagement is particularly vital. Engaged tourism employees are more likely to deliver exceptional service, handle customer complaints empathetically, and contribute to a positive work climate.

Furthermore, the Job Demands–Resources (JD-R) Model provides a comprehensive framework for understanding engagement. The model posits that job resources such as autonomy, feedback, and social support enhance engagement, while excessive job demands such as workload or emotional strain can diminish it. Tourism employees often face fluctuating workloads, emotional labor, and seasonal instability, making job resources a critical factor in sustaining engagement levels. When these resources are present, employees are more resilient, optimistic, and likely to invest additional effort in their jobs (Bakker & Bal, 2010).

2.2 Organizational Citizenship Behavior (OCB)

Organizational Citizenship Behavior (OCB) was conceptualized by Organ (1988) as discretionary, extra-role behavior that is not formally rewarded but contributes to organizational effectiveness. Unlike task performance, OCB goes beyond contractual job requirements and is driven by employees' intrinsic motivation and sense of belonging.

OCB has been extensively studied across different industries and cultural settings. Podsakoff et al. (2000) emphasized that OCB improves organizational efficiency by enhancing cooperation, reducing conflict, and fostering innovation. In service industries, especially tourism, OCB manifests in employees' willingness to assist colleagues, volunteer for additional duties, and create positive experiences for guests. Such behaviors directly impact customer satisfaction, loyalty, and the organization's reputation (Yen & Niehoff, 2004).

Researchers have also identified antecedents of OCB, which include job satisfaction, organizational commitment, perceived organizational support, and leadership quality (Bateman & Organ, 1983; Podsakoff et al., 2009). These antecedents overlap with those that influence employee engagement, suggesting a potential causal relationship between engagement and OCB. Employees who feel valued, trusted, and emotionally connected to their organization are more inclined to reciprocate through voluntary, citizenship-like behaviors that go beyond their formal roles.

2.3 The Relationship Between Employee Engagement and OCB

The theoretical link between employee engagement and OCB can be explained through Social Exchange Theory (Blau, 1964), which posits that human relationships are based on reciprocal exchanges. When employees perceive support, fairness, and recognition from their organization, they experience an obligation to reciprocate through positive behaviors, including OCB. Engagement serves as the psychological mechanism that transforms perceptions of organizational support into behavioral outcomes.

Saks (2006) empirically tested this theoretical framework and found that engagement acts as a mediator between perceived organizational support and OCB. Engaged employees are emotionally invested in their work and organization, leading them to go above and beyond their formal duties. Similarly, Bakker and Demerouti (2008) demonstrated that engagement leads to proactive behavior, creativity, and a willingness to help others, key components of OCB.

Karatepe (2013) extended this relationship to the hospitality and tourism sector, finding that engagement significantly predicts OCB among hotel employees. Engaged employees in hospitality settings are more likely to assist co-workers, display patience with guests, and advocate for their organization. The study concluded that engagement is a strategic resource that promotes service quality through enhanced discretionary behavior.

However, the dynamics of this relationship may vary across cultural and organizational contexts. In collectivist cultures, such as Indonesia's, employees may already possess a natural inclination toward cooperative and community-oriented behavior (gotong royong). In such settings, engagement may amplify an already strong cultural predisposition toward OCB. Conversely, in organizations with weak leadership or unclear communication, even highly engaged employees may experience frustration, reducing their likelihood of exhibiting OCB. Thus, understanding engagement OCB dynamics requires contextual consideration of both psychological and cultural factors.

2.4 Employee Engagement and OCB in the Tourism Context

Tourism organizations depend heavily on interpersonal relationships, teamwork, and emotional labor. Unlike manufacturing industries, where productivity can be measured through tangible outputs, the tourism industry relies on intangible elements such as service quality, empathy, and guest satisfaction, all of which are strongly influenced by employees' engagement and voluntary behavior.

In the case of Lau Gumba, Berastagi, tourism workers often face multiple job demands: long working hours, physical fatigue, high customer expectations, and limited job security. Despite these challenges, many continue to display strong community values and cooperative behavior. This makes Lau Gumba an ideal context for studying the dynamics between engagement and OCB, as both psychological and cultural factors interplay in shaping employee behavior.

Studies in Southeast Asia (e.g., Kim et al., 2017; Lyu, 2016) show that tourism employees' engagement enhances service quality, customer satisfaction, and organizational reputation. Moreover, engaged employees are more likely to exhibit OCB by voluntarily helping coworkers, showing empathy to guests, and participating in community-based tourism initiatives. This synergy between engagement and OCB contributes to sustainable tourism development by fostering positive internal culture and external service delivery.

Methods

This study uses a qualitative approach, which allows researchers to explore in depth the meaning, perception, and experience of stakeholders on the condition of the Drinking Water Supply System (SPAM) infrastructure in Simalungun Regency — including aspects of adequacy, reliability, service distribution, and projected future water needs. The qualitative approach was chosen because the issues raised are complex, contextual, related to socio-spatial conditions, policies, and perceptions of the community and management institutions. As explained by experts, qualitative methods are suitable for understanding phenomena in a natural context and generating an in-depth understanding of social realities that are difficult to measure solely with numbers.

3.1 Research Types and Design

This study is designed as a qualitative case study, where the "case" analyzed is the SPAM system in Simalungun Regency — including the distribution network, service management, and user and manager perceptions. The case study approach allows researchers to examine phenomena in real and complex contexts, including interactions between actors, demographic geographical conditions, and the dynamics of drinking water service conditions.

The selection of case studies is relevant considering district-scale research with diverse spatial/organizational characteristics, so that microstudies or quantitative surveys alone can ignore important contextual nuances.

3.2 Techniques and Data Sources

Data collection is carried out through several techniques in qualitative research, including:

1. In-depth / semistructured interviews with various stakeholders: SPAM managers / PDAM/related agencies, technical officers, village/sub-district heads (especially in sub-districts that have used SPAM for a long time), as well as representatives of users or service recipients to explore their perceptions, experiences, complaints, expectations, and views on the adequacy and reliability of drinking water services. Semi-structured interviews allow for the flexibility of exploring issues the researcher has a list of main topics, but can follow the flow of the conversation.
2. Field observation – visits to SPAM service areas, distribution networks, installation units, pipelines/distribution networks, and user residential areas. These observations provide a concrete picture of the physical condition, service distribution, network coverage, and whether there are indications of water loss, damaged pipes, uneven distribution, and raw water source conditions if relevant. The observational approach in field research is often recommended in qualitative studies of infrastructure.

3.3 Advantages of Qualitative Methods for This Study

Qualitative methods empower us to capture the complexity of reality not only in technical aspects, but also in social, institutional, perceptual and local contexts. In the case of SPAM in Simalungun Regency, things like spatial distribution, service reliability, public perception of water services, institutional management, operational and geographical challenges can all be well revealed through interviews, observations, and contextual analysis.

The method is also flexible and allows adjustments according to the situation in the field: for example, if an unexpected problem is found, the researcher can explore new aspects through follow-up interviews or additional observations of something that would be difficult to do in a routine quantitative approach.

Result and Discussion

4.1 The extent to which the capacity of SPAM in Simalungun Regency is able to meet the community's current clean water needs and future projections

The availability of adequate clean water is one of the important indicators in assessing the quality of public infrastructure, including the Drinking Water Supply System (SPAM). In Simalungun Regency, the current capacity of SPAM plays a role as the main source of clean water supply for the community. However, the ability of these systems to meet clean water needs is determined not only by the available water discharge, but also by the distribution of the pipeline, the number of household connections, the efficiency of the system, and the operational sustainability of SPAM. These factors determine whether the entire community gets sufficient, equitable, and continuous access to water.

Quantitatively, the capacity of SPAM must be compared with the community's water needs based on per capita consumption. Domestic clean water consumption standards in Indonesia generally range from 90–120 liters per person per day, with variations depending on the characteristics of the region, such as urban or rural. Using this standard and data on the current population of Simalungun Regency, the estimated daily need for clean water can be calculated. If the available SPAM capacity is above the total theoretical requirement, nominally the system is considered sufficient. However, field conditions often show a gap between capacity and service realization, for example because some households are not connected to the SPAM network, water loss in the pipeline (Non-Revenue Water / NRW), or uneven distribution pressure.

Looking to the future, the projected water demand must take into account population growth, urbanization, and changes in consumption patterns. The need for clean water is expected to increase along with the increase in the number of households and domestic and non-domestic activities. If SPAM capacity is not increased or the distribution network is not expanded, potential for a shortage of clean water supply will arise, especially in developing areas or newly connected rural areas. Therefore, long-term planning of SPAM needs to use a needs-based approach, including increasing the discharge of water sources, expanding the distribution network, improving system efficiency, and reducing water leakage.

The reliability aspect of the SPAM system is also important in assessing the ability to meet needs. Reliability includes not only the adequacy of the amount of water, but also the continuity of supply, equitable distribution, and quality of water that is safe to consume. By paying attention to these indicators, the evaluation of SPAM capacity can provide a clearer picture of the extent to which the current system is able to meet the needs of the community and how ready SPAM is to meet future demand. Thus, this research is important to identify critical areas, formulate development strategies, and ensure sustainable clean water services for all people of Simalungun Regency.

4.2 How reliable is the SPAM system in ensuring the continuity of clean water supply, distribution efficiency, and water source reserve

The reliability of the SPAM (Drinking Water Supply System) system is a crucial aspect in ensuring the availability of sustainable clean water for the community. The level of reliability is not only related to the water discharge capacity, but also the continuity of supply, even distribution, operational efficiency, and readiness to deal with emergencies or fluctuations in demand. A reliable SPAM system must be able to keep the water supply stable despite changes in consumption, technical disruptions, or the dry season, so that people can access clean water consistently.

One of the indicators of reliability is continuity of supply. A reliable SPAM system ensures that water is available at all times and is able to cover people's daily peak needs. In Simalungun Regency, water production capacity is currently mostly able to meet average needs, but variations in demand in some areas — especially in urban centers or developing areas — can put distribution pressures. Technical disturbances in processing plants or pipelines, such as pump failures or leaks, can reduce supply continuity. Therefore, reliability evaluations should include the system's ability to minimize disruptions and recover quickly when technical issues occur.

In addition to continuity, distribution efficiency is an important factor. Distribution efficiency includes minimizing water loss (Non-Revenue Water (NRW), optimal pipe pressure management, and equitable distribution to all service areas. High leakage rates or uneven water pressure can cause some households to receive a limited or uneven supply. The reliability of distribution depends on the quality of the pipeline, regular maintenance, and good monitoring

and operational control. An efficient system is able to optimally distribute clean water according to the installed capacity without waste or unevenness.

The backup water source is also an important component in assessing reliability. A reliable SPAM system needs to have sufficient spare capacity to anticipate emergency conditions, such as seasonal droughts, damage to major water sources, or sudden surges in demand. The availability of these backups ensures that the system can remain operational without disrupting service continuity, while providing flexibility in distribution and maintenance management. Reserve planning must consider population growth and projected future water needs to remain able to meet demand reliably.

Thus, the reliability level of SPAM in Simalungun Regency is not only assessed from the nominal capacity of the system, but also from the ability to maintain supply continuity, distribution efficiency, and readiness to face emergency conditions. A thorough evaluation of these three aspects will provide an overview of the extent to which the current SPAM system can meet the community's clean water needs and prepare for sustainable services in the future.

4.3 What are the factors that affect the adequacy and reliability of SPAM in Simalungun Regency

The adequacy and reliability of the Drinking Water Supply System (SPAM) is influenced by various interrelated factors, both from the technical, managerial, and social and environmental contexts. One of the main factors is the capacity of the water source. Raw water discharge, availability of reserves, and quality of water sources determine the ability of SPAM to meet the daily needs of the community. If water sources are limited or fluctuate due to the dry season or local hydrological conditions, then the adequacy of clean water supply will be affected, even though the distribution system has a large nominal capacity. Therefore, effective water source management is the foundation for system reliability.

The second factor is the capacity and condition of the distribution infrastructure. Pipelines, pumps, reservoirs, and water treatment plants must be adequate enough to distribute water throughout the service area evenly. Pipe damage, leaks, or unstable water pressure can reduce continuity and impair distribution efficiency, so some communities receive a limited amount of clean water. Excellent technical conditions and regular maintenance are decisive factors in maintaining the reliability of SPAM.

In addition, the management and operations of SPAM also have a big influence. The reliability of the system depends not only on physical means, but also on the manager's ability to monitor discharge, regulate pipeline pressure, handle technical faults, and plan preventive maintenance. Good management practices, including the use of periodic monitoring and evaluation technologies, will improve distribution efficiency and minimize water loss. On the other hand, management weaknesses can magnify the risk of service interruptions and lower system reliability.

Population growth factors and water demand patterns are other important considerations. The adequacy and reliability of SPAM are also influenced by the dynamics of the population, urbanization, and increasing domestic and commercial needs. Systems designed for current capacity may not be adequate for future needs if projected growth and consumption patterns are not taken into account. Therefore, planning based on projected water needs is crucial to ensure that SPAM remains reliable in the long term.

Environmental and regulatory factors also influence. Hydrological conditions, climate, availability of land for reservoirs or distribution networks, as well as compliance with water quality regulations and standards, are additional aspects that must be considered. By paying attention to all these factors holistically, the evaluation of the adequacy and reliability of SPAM in Simalungun Regency can be carried out comprehensively, as well as producing strategic recommendations for the sustainable development of clean water systems.

4.4 What are the recommendations for the development strategy of SPAM in order to meet the community's clean water needs in a sustainable manner

The development of a sustainable Drinking Water Supply System (SPAM) requires a comprehensive strategy, covering technical, managerial, and socio-economic aspects. One of the main strategies is to increase the capacity of water sources. This can be done through the exploration of additional water sources, the construction of deep wells or reservoirs, and the conservation of existing water sources. Increasing the capacity of water sources not only increases the available discharge, but also strengthens reserves to deal with dry seasons or fluctuations in demand, so that continuity of supply can be maintained.

In addition, the expansion and improvement of the distribution network is an important step. Pipelines, reservoirs, and pumps should be expanded to cover all unserved areas, including new settlements and remote rural areas. Repairing networks that are old or frequently leaking are also indispensable to improve distribution efficiency. With an even distribution and minimal leakage, SPAM will be better able to reach the entire community and maximize available capacity.

The next strategy is to strengthen SPAM management and operations. Increasing human resource capacity, utilizing monitoring technology, and implementing performance-based management will help maintain system reliability. For example, the use of flow sensors, SCADA (Supervisory Control and Data Acquisition) systems, or digital applications for network monitoring can minimize water loss, detect disturbances faster, and optimize distribution settings. This approach also increases transparency and operational accountability, making clean water services more reliable.

In addition to technical and managerial aspects, planning based on projected needs is key in the development of long-term SPAM. By analyzing trends in population growth, urbanization, and changes in water consumption patterns, managers can adjust system capacity, add household connections, and prioritize network construction in areas that will experience increased demand. This strategy ensures that SPAM remains relevant and able to meet the needs of the community in the future.

Finally, environmental sustainability approaches and community participation also need to be considered. Environmentally friendly management of water resources, pollution reduction, and public education about water conservation will support the sustainability of the system. Community participation in network monitoring and maintenance can improve water use compliance and lower the risk of water loss. With a combination of technical, managerial, projected needs, and community participation, SPAM in Simalungun Regency can develop sustainably and ensure sufficient, equitable, and reliable clean water supply for the entire community.

Conclusion

Based on the results of the analysis, this study concludes that the SPAM capacity in Simalungun Regency is currently nominally able to meet the average clean water needs of the community, especially in urban areas and areas that already have a distribution network. However, there are service gaps in some rural areas or new settlements that are not fully connected, as well as network leaks and water pressure variations that reduce distribution effectiveness. This shows that although the total water supply is sufficient, equitable distribution and continuity of service still need to be improved.

The reliability level of SPAM is influenced by the continuity of supply, distribution efficiency, and water source reserves. The current system shows sufficient capacity to meet average daily demand, but is vulnerable to demand fluctuations, technical glitches, and dry weather conditions. Distribution efficiency is also affected by network leakage and uneven

coverage of household connections. The current water reserve needs to be strengthened so that the system can cope with emergencies or increased needs in the future.

The study also found that factors affecting the adequacy and reliability of SPAM include the capacity and quality of water sources, the condition of distribution infrastructure, operational management, population growth and water demand patterns, as well as environmental and regulatory factors. An imbalance of one of these factors can have a direct impact on the availability and continuity of services for the community.

As a follow-up, the study recommends a sustainable SPAM development strategy, which includes increasing water resource capacity, improving and expanding distribution networks, strengthening management and operational monitoring, needs projection-based planning, and community participatory and environmental conservation approaches. With the implementation of this strategy, SPAM in Simalungun Regency is expected to be able to meet the needs of clean water in an equitable, reliable, and sustainable manner, both now and in the future.

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