Strategy and Master Plan for Water Supply and Domestic Wastewater in Klungkung Regency, Bali

I Y Septiariva¹, I W K Suryawan²*, S Suhardono³, E S Sofiyah², N L Zahra²

¹Faculty of Engineering, Department of Civil Engineering, Universitas Sebelas Maret, Surakarta 57126, Indonesia
²Faculty of Infrastructure Planning, Department of Environmental Engineering, Universitas Pertamina, Jakarta 12220, Indonesia
³Faculty of Mathematics and Science, Department of Environmental Science, Universitas Sebelas Maret, Surakarta 57126, Indonesia
*corresponding author: i.suryawan@universitaspertamina.ac.id

Abstract. Klungkung Regency is the second smallest regency/city area after Denpasar City. The declaration of the Indonesian government in meeting the MDG’s target for zero slums has been followed by the district government of Klungkung with a focused policy and strategic direction. The identification of slum issues is carried out on several indicators for the conditions of water supply and wastewater services. The purpose of this paper is to make long-term planning to realize integrated domestic wastewater treatment until 2033. This research uses a qualitative approach with descriptive methods and data analysis was performed by data display, verification, and conclusion drawing. To overcome the problem of fulfilling raw water, efforts are made to handle it through plans for phases I, II, III, and IV. In the period from 2019-2023, a drinking water supply system will be developed by utilizing raw water from the Muara Unda Reservoir, which is 300 L/sec. In phase III, a transmission unit will be built in the raw water delivery system from the Penida Spring with an additional capacity of 20 L/sec. In Klungkung Regency, there is no centralized wastewater treatment plant to treat wastewater from this domestic activity. Most residents in Klungkung Regency dispose of their domestic waste/water through septic tanks (for black water), while gray water is directly channeled into drainage channels or directly discharged into rivers.

1. Introduction
To support the achievement of the Sustainable Development Goal’s (SDG’s) target in 2025, which is the coverage of piped water services in urban areas by 80% (eighty percent) and in rural areas by 60% (sixty percent), local governments need to strengthen the capital structure Regional Water Company (PDAM). For achieving the (SDG’s) target, the Indonesian government has worked hard to deal with slum zero planning. The initial step in pursuing the slum zero target has been started by the Ministry of Public Works by compiling slum handling road map and updating slum data that are carried out collaboratively with relevant ministries/institutions and local governments throughout Indonesia. Slum points that have been set include the condition of buildings, environmental road conditions, drainage conditions, drinking water supply, waste management, and wastewater treatment [1]. Then the identification of slum issues is carried out on several indicators for the conditions of water supply and waste management. Most of
the area has a drinking water supply system that does not meet the technical requirements and the scope of existing drinking water supply services is inadequate to the population.

Klungkung Regency has an area of 315 hectares or 5.60% of the total area of Bali Province and is the second smallest regency/city after the city of Denpasar. The area of Klungkung Regency is divided into two parts, namely Klungkung Islands (Nusa Penida Islands) is 20.284 ha (2/3 of the total area) and the Klungkung area on the island of Bali is 11.216 ha. Klungkung Regency consists of four districts namely Klungkung District, Banjarangkan District, Nusa Penida District, and Dawan District. Hydrologically, Klungkung Regency has water resources from rivers and springs. Rivers that flow throughout the year are only found in the Klungkung Mainland area, while the water source in Nusa Penida Sub-district is a spring and rainwater accommodated in RWS (rainwater harvesting) [2].

The fulfillment of SPAM (drinking water distribution system) raw water in Klungkung Regency is currently not able to meet the needs of raw water until 2018. The ability of SPAM infrastructure is relatively limited for the SPAM service area of PDAM (local water company) in Klungkung Regency due to the limited fulfillment of raw water (RISPAM, Master Plan 2033). Meanwhile, achieving universal access in the sanitation sector targets 85% of Indonesia's population to receive sanitation services by means that 85% of the population has access to adequate on-site basic sanitation facilities in the wastewater sector. While 15% of the population has access to communal/regional/municipal scale wastewater treatment systems [3], municipal wastewater is also the main issue besides industrial wastewater like textile [4, 5, 6] and hotel [7, 8] in Klungkung Regency.

Therefore, this paper aims to make long-term planning to realize integrated domestic wastewater treatment until 2033, which functions to developing wastewater service systems as well as improving access to infrastructure and facilities for wastewater, as the augmentation for achieving 100 percent drinking water services and improve public accessibility to adequate drinking water services.

2. Method
This research uses a qualitative approach with descriptive methods. Data sources were obtained from water supply planning and wastewater treatment documents. The water supply policy was taken from the document of the Klungkung Regency Water Supply System/Rencana Induk Sistem Penyediaan Air Minum (RISPAM) Master Plan 2015-2033 [9]. Furthermore, the data for the management of wastewater was taken from the Klungkung Regency Sanitation Strategy/Strategi Sanitasi Kabupaten Klungkung 2016-2021 document [3]. Lastly, data analysis was performed by data display, verification, and conclusion drawing.

3. Result and Discussion

3.1. Management of Water Supply in Klungkung Regency
The need for water supply in Klungkung Regency has been planned since 2015. Data in 2014 states that the Banjarangkan, Dawan, Klungkung, and Nusa Penida sub-districts can provide 62 L/s, 55 L/s, 93 L/s, and 75 L/s respectively (Figure 1). Based on the projections made by the government, water demand in Klungkung Regency continues to increase every year. The required water supply calculation is based on the planning phase. The planning phase of developing water supply systems in Klungkung Regency is divided into four phases. The first phase (phase I) in 2015-2018, the second phase (phase II) in 2019-2023, the third phase (phase III) in 2024-2028, and the fourth phase (phase IV) in 2029-2033 (RISPAM, 2015).

Water services must increase every year as the level of drinking water service in Klungkung Regency has reached 60.63% in 2015 [9]. In the plan, the service level is planned to continue to increase at each planning stage and has reached 100% drinking water service in 2023. The inhabitants of Klungkung Regency tend to use house connections (SR) from the PDAM (Table 1). The lowest total service was in Nusa Penida Subdistrict which was only able to serve 21.07%. Research conducted by Purbadharmaja et al., states that 81.61% of the water supply came from water companies (PDAMs) and only 18.39% used wells and rainfed. The data is still relatively high compared to the field data which only shows
21.07% [10]. It is estimated that the number of samples taken from the study is only 174 capita, while the population of the Nusa Penida Sub-District reaches 45,460 people [11]. Village community participation in Klungkung Regency through the Village Water Company (PAMDES) program has already taken place in the Klungkung Subdistrict, Banjarangkan Subdistrict, and Dawan Subdistrict. The level of community participation in the village as measured by Participatory Rural Appraisal (PRA) is influenced by unwritten regulations regarding applicable rules [12].

![Figure 1](image_url)

**Figure 1.** Projection of Water Demand (L/s) and Water Supply Services (%) in Klungkung Regency [9]

| Sub District   | PDAM (%) | PAMDES (%) | Total Services (%) |
|---------------|----------|------------|--------------------|
|               | House Connection (HC) | Public Hydrants (PH) | House Connection (HC) | Public Hydrants (PH) |
| Klungkung     | 79,1     | 1,3        | 6,0                | 0,0                 | 86,39               |
| Banjarangkan  | 73,7     | 3,3        | 2,3                | 0,2                 | 79,41               |
| Dawan         | 46,3     | 2,4        | 6,9                | 0,0                 | 55,66               |
| Nusa Penida   | 19,7     | 1,4        | 0,0                | 0,0                 | 21,07               |
| **Average**   |          |            |                    |                     | **60,63**           |

3.2. Water Supply Planning in Klungkung Regency

The water supply development plan in Klungkung Regency is divided into four phases. Each planning phase in Table 2 shows the focus of the development of Nusa Penida Island and Nusa Lembongan Island. Furthermore, in the mainland area phase I is focused on Dawan Subdistrict, phase II is focused on Banjarangkan Subdistrict, phase III is focused on Klungkung Subdistrict, and the fourth phase is focused on the development strategies for each region which were seen to achieve 100% water services. The map of water springs distribution can be seen in Figure 2.
### Table 2. Implementation Plan for Provision of Drinking Water to Communities in Kelungkung Regency [9]

| No | Planning Process | Implementation Details | Location |
|----|------------------|------------------------|----------|
| 1  | Phase I (2015 – 2018) | Study on optimizing the capacity of the Guyangan Spring and Penida Spring | Nusa Penida Island, Nusa Penida Subdistrict |
|    |                  | Construction of transmission units at Guyangan Spring and Penida Springs with a capacity of 35 L/s | Nusa Penida Island, Nusa Penida Subdistrict |
|    |                  | Development of a Distribution Network in the raw water supply system of the Guyangan Spring and the Penida Spring | Nusa Penida Island, Nusa Penida Subdistrict |
|    |                  | Construction of water supply with 15 L/s with reverse osmosis technology in Nusa Lembongan Island | Nusa Lembongan Island, Nusa Penida Subdistrict |
|    |                  | Study on the development and utilization of ground water | Dawan Subdistrict |
|    |                  | Construction of transmission and distribution units by using wellbore | Dawan Subdistrict |
|    |                  | Optimization and development rural drinking water management (PAMDES) | Dawan Subdistrict |
| 2  | Phase II (2019 – 2023) | Continued development of the distribution network in the raw water supply system of the Guyangan Springs and the Penida Springs | Nusa Penida Island, Nusa Penida Subdistrict |
|    |                  | Continued Development of a main water supply distribution network with reverse osmosis technology in Lembongan | Nusa Lembongan Island, Nusa Penida Subdistrict |
|    |                  | Development of the distribution network in the raw water supply system of the Muara Tukad Unda Phase I Reservoir of 300 L/s | Klungkung Subdistrict, Dawan Subdistrict, and Banjarangkan Subdistrict |
|    |                  | Study on optimizing the capacity of Banjarangkan water supply on the transmission and distribution unit network at Bangbang Springs | Banjarangkan Subdistrict |
|    |                  | Development of Banjarangkan water supply on the transmission and distribution unit network at Bangbang Springs. | Banjarangkan Subdistrict |
|    |                  | Optimization and development rural drinking water management (PAMDES) | Banjarangkan Subdistrict |
| 3  | Phase III (2024 – 2028) | Study on optimizing the capacity of the Klungkung water supply unit in the transmission and distribution unit network at the Gesing Spring | Klungkung Subdistrict |
|    |                  | Development of Klungkung water supply on the transmission and distribution unit network at Gesing Springs. | Klungkung Subdistrict |
|    |                  | Construction of transmission units at Guyangan Spring and Penida Springs with an additional capacity of 20 L/s. | Nusa Penida Island, Nusa Penida Subdistrict |
|    |                  | Development of the distribution network in the raw water supply system of the Muara Tukad Unda Phase II Reservoir addition of 50 L/s | Klungkung Subdistrict |
|    |                  | Continued Development of a main water supply distribution network with reverse osmosis technology in Lembongan (additional 5 L/s) | Nusa Lembongan Island, Nusa Penida Subdistrict |
In the area of Nusa Penida Island, there are Guyangan Springs and Penida Springs utilized by the PDAM. Penida Springs located in Sakti Village, before being distributed to the community, the water is treated at a water treatment plant with a water treatment capacity of 20 L/s [13]. Currently, Penida Springs only reach a number of villages, namely Sakti Village, Toyapakeh Village, Ped Village, Kutampi Village, Batununggul Village, and Suana Village [13]. Guyangan Springs is the most potential spring with a discharge capacity owned by the Guyangan water source of 178 L/s, while the production capacity is 2 L/s [13]. Moreover, there are five springs that cannot be utilized on Nusa Penida Island, namely Seganing Springs, Tembeling Springs, Tabuanan Springs, and Wates Springs.

| Objective | Area |
|-----------|------|
| Development and installation of distribution pipes from reservoirs in the raw water supply system and up to planned service blocks. | Klungkung Region |
| Addition of pipes in the main distribution pipelines and in parallel | Klungkung Region |
| Expansion of distribution pipelines in water supply units, especially those that have not been reachable or new residential areas | Klungkung Region |
| Maintain the level of leakage | Klungkung Region |
| Placement of valves and other accessories at certain points to regulate flow | Klungkung Region |
| Substitution of water meter that is broken or not functioning properly | Klungkung Region |
The people of Nusa Lembongan Island and Nusa Ceningan Island are served with limited groundwater with quite good water quality [13]. Groundwater exploration causes land subsidence [14]. Hence, it is suitable to build a water supply planning in Nusa Lembongan with reverse osmosis technology. Additionally, over electricity supply is not a problem of this planning because some previous studies have suggested that power systems using wind-photovoltaic-diesel-batteries with reverse osmosis systems with a capacity of 1 m3/h used on Bozcaada Island, Turkey gave satisfactory results [15]. Some studies also mention renewable energy such as wind energy potentially applied to saline water reverse osmosis (SWRO) seawater units [16, 17].

3.3. Management of Domestic Wastewater in Klungkung Regency

The management of domestic wastewater in Klungkung Regency has utilized Septic Tanks. Basic access to sanitation with the use of unfase septic tanks and culbuk shows values that tend to be the same for each subdistrict. The rate of use of unfase septic tanks and culbuk is quite low compared to other regions, especially for small island areas such as Nusa Penida Subdistrict. 53% sewage disposal found in Penyengat Island was simple pit sewage which potentially exerts bad impacts on the soil and seawater [18]. Syamsir et al., showed that the main parameter of pollution in the island area is coliform [19]. Maintaining public health and the environment on Nusa Penida Island, Nusa Lembongan Island, and Nusa Ceningan Island is very important because the sustainability of the tourism sector depends on the proper environment.

Recently discovered emissions from the use of Soakaway Septic Tank amounted to 15.0 kg yr$^{-1}$ more CO2 [20]. This, of course, causes the selection of processing with off-site systems to be a priority.
in the long-term development in Klungkung Regency. However, the management of wastewater with an off-site system has not yet been applied. Research on Antiparos Island, Greece states that domestic wastewater with off-site constructed wetlands systems has fewer emissions compared to on-site constructed wetlands systems [21]. The results of data processing in Dawan Subdistrict, Banjarangkan Subdistrict, and Nusa Penida Subdistrict showed open defecation behavior exceeding 30% (Table 3). Open defecation behavior is one of the challenges of the developing world and causes the transmission of diarrheal diseases [22]. Harter et al., stated that open defecation is a major source of environmental pollution and the leading cause of death [23].

**Table 3.** Condition of Domestic Wastewater Management in Klungkung Regency (SSK, 2016)

| Subdistrict | On-site system (%) | Off-site system (%) | Basic access (%) | Open Defecation (%) |
|-------------|--------------------|---------------------|------------------|---------------------|
|             | Septic tank        | Communal Septic tank| MCK             | Regional scale WWTP | City scale WWTP | Unsafe septic tank | Cubluk |
| Klungkung   | 87,34              | 0,21                | 0,02             | 0,00                | 0,00          | 2,05               | 0,60  | 9,79  |
| Dawan       | 65,67              | 0,25                | 0,02             | 0,00                | 0,00          | 2,27               | 0,87  | 30,92 |
| Banjarangkan| 62,33              | 0,31                | 0,03             | 0,00                | 0,00          | 2,13               | 1,07  | 34,13 |
| Nusa Penida | 61,74              | 0,16                | 0,02             | 0,00                | 0,00          | 2,75               | 0,84  | 34,48 |

3.4. Domestic Wastewater Planning in Klungkung Regency

The wastewater treatment sector is still undefined as development plans to be implemented. To facilitate the infrastructure of the wastewater system, the government planned for the preparation of a master plan and an outline plan for the Klungkung Regency wastewater system. However, a Regional Regulation on Management of Klungkung Regency domestic wastewater is needed. The wastewater service plan that will be carried out for Klungkung Regency consists of short-term plans, medium-term plans, and long-term plans. The overall wastewater treatment services planning can be seen in Figure 3. The utilization of individual septic tanks is expected to reach 100% for long-term plans, whereas the use of communal wastewater treatment is not a priority. WWTP for Semarapura City and regional scale planned long-term has been able to serve 10% and 40% of the total population (Figure 4.). Open defecation must be eliminated in long-term planning since this planning is carried out to prevent the transmission of diarrheal diseases. Unsafe domestic wastewater management produces high nutrients [24]. The nutrient content in water can cause environmental degradation, one of which is eutrophication [25, 26].

City scale WWTPs are planned in Semarapura City, while regional scale WWTPs are planned in Lembongan Village, Banjarangkan Village, Dawan Kaler Village, and Batununggal Village. Two of these locations are on the island, namely Lembongan Village and Batununggal Village. MCK++ is planned in Lembongan Village, Gelgel Village, Semarapura City, and Batununggal Village. MCK++ is a building for washing the toilet with a sink and a single rinse. The construction step of MCK++ is the same as the construction step of WWTP, which includes training in technical, financial, and managerial fields. However, the scope of MCK++ planning is narrower compared to WWTP.
**Figure 3.** Map of wastewater treatment services planning in Klungkung Regency

**Figure 4.** Projection of wastewater management services in Klungkung Regency (SSK, 2016)
The steps that must be carried out in achieving these goals are counseling and campaigns to encourage community participation in the management of domestic wastewater, especially in areas that have the potential to build WWTPs and MCK++. Socialization of Communal WWTP and MCK++ development is publicized by the Government-Related Office. To increase community participation, it is necessary to form a self-help group (KSM-SANIMAS) and training for KSM-SANIMAS management in the form of training in technical, financial, and managerial fields. After increasing the soft skills and hard skills of KSM-SANIMAS management, socialization was carried out to the community. After the non-technical aspects have been completed, the planning and construction of WWTPs, sewerage systems, and house connections as well as operation and maintenance of WWTP are then conducted by KSM-SANIMAS. Family support and business potential are the main factors for the success of the KSM-SANIMAS program [28]. Improving the planning of the city scale and regional scale of WWTPs in Klungkung Regency in which KSM-SANIMAS needs careful technical guidance.

Conclusion
To achieve the goal of improving the quality of settlements, including reaching Universal Access 100-0-100 where 100% of the population has access to adequate drinking water and 100% of the population has access to adequate sanitation. The problem faced is the lack of access to drinking water and wastewater facilities and infrastructure for the community. The percentage of drinking water service with the achievement in 2013 was 56.45% of the planned achievement in 2018 (end of planning) by 85%; meanwhile, percentage improvement of wastewater services with service achievements in 2013 was 62.41%, the planned achievement in 2018 (end of planning) was 68.91%. Local system (on-site) wastewater treatment was carried out individually by providing wastewater treatment tanks or septic tanks. Phase III plan is the fulfillment of drinking water needs with a period of years (2024-2028). Construction of transmission units in drinking water delivery systems (SPAM) from Penida Springs was 20 L/s of additional capacity; construction of SPAM in Lembongan with reverse osmosis was 5 L/s of additional capacity; Development of the Main Distribution Network (JDU) and JDB in the raw water supply system of the Muara Tukad Unda Reservoir (50 L/s) was a source of raw water for drinking water.

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