Analysis of Water Demand and Planning of Master Pipe in Pecatu Village, South Kuta Subdistrict, Badung Regency

Kristina Marta Nainggolan[1], Ida Bagus Made Baskara Andika[2*]
Udayana University, Bali, Indonesia
E-mail address: kris.tinangl0911@gmail.com[1], ibmbaskara@unud.ac.id[2*]

ABSTRACT

Pecatu Village is one of the areas located in South Kuta, Badung Regency which is still experiencing an increase in drinking water demand due to the increasing population every year. The source of clean water needs in Pecatu Village is managed by Perumda Air Minum Tirta Mangutama Badung Regency. The problem that occurs in Pecatu Village is the lack of clean water distribution to all residents who have subscribed or not subscribed to Perumda Air Minum Tirta Mangutama. Therefore, it is necessary to analyze the need for drinking water and planning the size of the main pipe network in Pecatu Village. This research was conducted by projecting the population of Pecatu Village with a period of 10 years to 2033 using the Least Square method. The results of the analysis showed that the population of Pecatu Village in 2033 was 8839 people with a maximum day demand of 22.10 L/s and water loss of 2,946 L/s. The main pipe planning is made into 4 segments which are placed based on the grouping of public roads based on their function with pipe diameters of 8 inch and 6 inch.

Keywords: *Water Demand, Water Supply System*, *Water Distribution Network*

1. INTRODUCTION

Population growth worldwide greatly increases the demand for clean water for various sectoral water uses (e.g. irrigation, domestic, energy, manufacturing uses)[1]. Water scarcity refers to the lack of clean water resources to meet water demands. Water scarcity is still a major concern in some parts of the world, and is listed as one of the biggest global risks. Severe droughts have hit Europe, the United States and Australia in recent years, with significant socio-economic, environmental and ecological impacts[2]. Communities in some areas of Indonesia still experience water shortages due to drought/water crisis during the long dry season. Problems in water supply in Indonesia still occur frequently due to the level of drinking water services, water quality and quantity as well as inadequate supply and distribution[3].

One of the areas in Indonesia that is still experiencing a water crisis to date is South Badung, precisely in Bali. The increasing population in Badung Regency causes the need for clean water for the community, especially in the South Badung Regency area, to increase due to the increasing population [4]. Destinations and tourist development centers in Bali are experiencing symptoms of a clean water crisis for example in the construction of tourism accommodation, especially star hotels, which are rapidly in the South Badung area, Bali, causing. In the Pecatu area, South Kuta, the community is experiencing a clean water crisis because the drinking water supply system from Perumda Tirta Mangutama Badung Regency is not well distributed. The existing problem is that the stored water discharge cannot be flowed to South Kuta, because it is constrained by the existing condition of the main network which is old and has limited capacity. This resulted in the old water pipe installation no longer able to distribute water ideally according to community demand [4]. This is experienced by nearly 100 families, especially those in the Bukit area. The condition of the Pecatu Village area makes water unable to be channeled optimally. Even to get underground water is almost impossible because the type of soil in Pecatu Village is limestone soil. To get clean water, residents must buy clean water for their daily needs where the price for 1 liter of a 5,000 liter water tank can reach Rp 250 thousand to Rp 300 thousand and the price becomes more expensive if the distance of residents' homes is far away so that it takes longer travel time [5].

PDAM Tirta Mangutama Badung Regency serves the Kuta and South Kuta areas where one of the Water Treatment Plants (IPA) in the Kuta and South Kuta District areas is located at Estuary DAM [4]. The household sector is the largest water user in Badung Regency with a water volume of 11,364,582 m3 / year, followed by the hotel sector with water usage of 5,618,801 m3 / year, then the industrial sector with a water volume of 1,510,096 m3 / year and for public facilities has a water volume of 1,335,624 m3 / year [6]. Through the existing problems, a solution was found by planning the size of the main pipe network to be able to serve the entire population in Pecatu Village. This research was conducted to analyze the need for drinking water in Pecatu Village and plan the size of the main pipe network in Pecatu Village so that in the future the need for drinking water for the residents of Pecatu Village is met as a whole.

2. THEORY AND METHODS

2.1 Theory

A. Drinking Water System

The Drinking Water Supply System consists of several units:

1) Raw Water Unit

Raw Water is water whose source origin is from surface water, groundwater, rainwater and sea water that has met the quality standards of raw water to be used as drinking water. Facilities and infrastructure for the collection and / or provision of raw water, which includes water storage buildings, retrieval / tapping buildings, measurement tools, and monitoring equipment, pumping systems and carrier facilities and equipment [7]. Raw water sources can come from surface water (rivers, swamps, lakes, reservoirs), rainwater, and groundwater.

2) Transmission Unit

The transmission unit is a unit in SPAM that functions to channel or flow raw water to the production unit (raw water transmission system) or channel the processed products of the production unit to the distribution reservoir (drinking water transmission system). The channel in the transmission unit is divided into 2 (two) streams, including:

a. Transmission lines in free or unpressurized flow, consisting of Open Canals, Aquaducts, Tunnels, and others.
b. Transmission lines for pressurized flow.

3) Production Unit

Production units are facilities and infrastructure that can be used to treat raw water and then become drinking water through physical, chemical and/or biological processes. The production unit includes processing buildings and equipment, operational devices, measurement tools and monitoring equipment, and drinking water storage buildings [8].

4) Distribution Unit

The Distribution Unit is a means of distributing drinking water from the storage building to the service unit, including distribution networks and equipment, storage buildings and measurement and monitoring equipment [8].

5) Service Unit

Drinking water service units consist of house connections (sr), public faucets and public hydrants. House connections are piping connections originating from distribution pipes which will then be distributed to homes. SR piping only supplies pipe connections to the front of the house which are equipped with saddle clamps, water meters, stop taps, plug taps and unidirectional valves. However, for installation inside the house is the responsibility of the homeowner [8].

6) Management Unit

The management unit consists of 2: technical management and non-technical management. Technical management include operational, maintenance and monitoring activities of raw water units, production units and distribution units and for non-technical management consists of administration and services.

B. Pipe Type

Fulfillment of the community's basic needs for proper clean water is a growing problem in Pecatu Village. The distribution of clean water is uneven, so that some communities / residences have not received clean water optimally [9]. The clean water network system is a system used to distribute clean water starting from raw water collection to service to customers that meet the requirements of drinking water quality standards [10]. The clean water transmission system is a system consisting of long pipes that carry water from the reservoir to the distribution network where consumers are located [11]. The distribution network is a series of pipes that are connected and used to deliver water to consumers. The distribution layout is determined by the topographical conditions of the service area and the location of the treatment plant [12]. Clean water distribution piping networks can be classified as follows [13]:

1) Distribution Conduit Pipe
   a) Main Master Pipe
      The main main pipe is a distribution pipe that has the widest coverage and the largest diameter. Its function is to serve and distribute to each service block, and each block has one or two tapping points connected to the secondary main pipe.
   b) Secondary Master Pipe
      Secondary main pipe is the second type of transmission of a network system. Water will be forwarded from the main main pipe to each service block. This pipe has a branch to the service pipe.
2) Distribution Service Pipe
   The distribution service pipe is a secondary main pipe that is tapped and directly serves consumers. The diameter used is determined on the magnitude of service to consumers. This pipe system can be divided into the following:
   a) Branch pipes can deliver directly to the house and can deliver to smaller pipes.
   b) Pipe Service This pipe is a pipe for home connections.

2.2 Methods

A. Research Location

The location of this research was conducted in Pecatu Village which is presented in Figure 1.

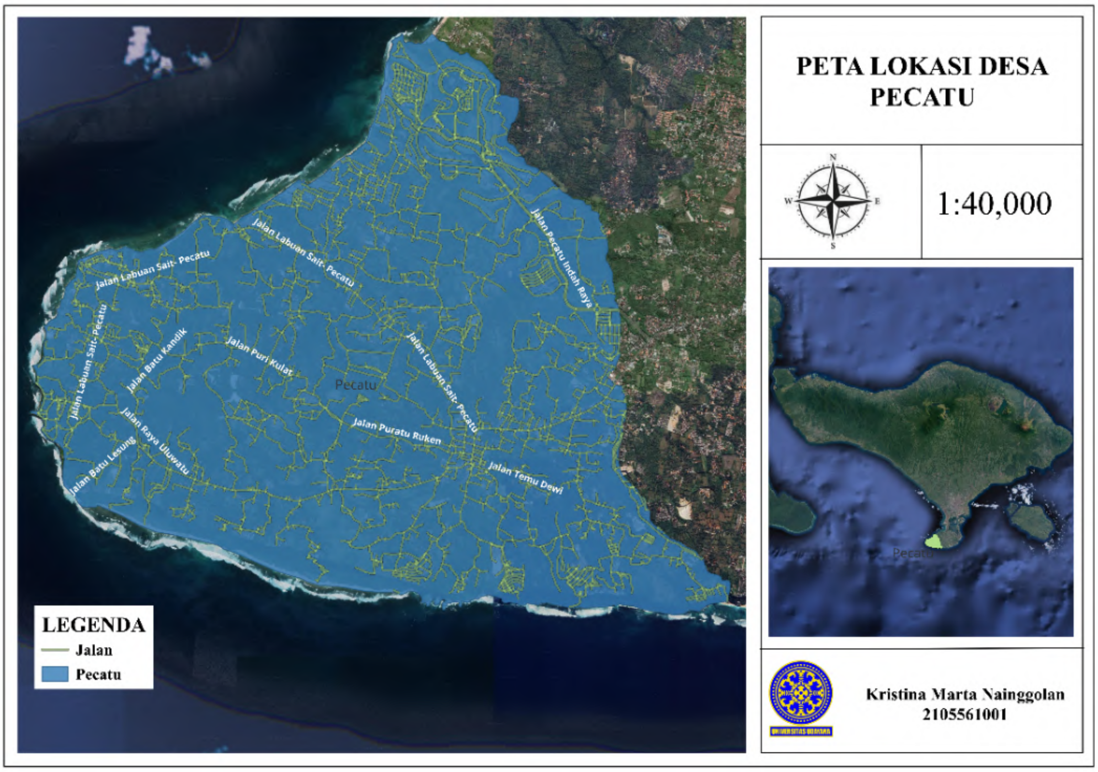

Figure 1. Pecatu Village

B. Analysis of Water Demand

1. Population Projection

In SPAM planning, population projections are needed to estimate the fulfillment of clean water needs in the service area. The calculation of population projections can be done by several methods, including arithmetic, geometry, and least square.

Arithmetic Method

$$P_n = P_0 + Ka(n)$$

Geometry Method

$$P_n = P_0 (1+r)^n \qquad \text{dengan} \qquad r = \left(\frac{P_n}{P_0}\right)^{\frac{1}{n}} - 1$$

***Least Square* Method**

$$P_n = a + b(n)$$

$$a = \frac{(\Sigma P).(\Sigma t^2) - (\Sigma t).(\Sigma Pt)}{n.(\Sigma t^2) - (\Sigma t)^2}$$

$$b = \frac{n.(\Sigma Pt) - (\Sigma t).(\Sigma P)}{n.(\Sigma t^2) - (\Sigma t)^2}$$

The most effective projection calculation method is the one with the smallest standard deviation. Here is the calculation formula to determine the standard deviation.

$$SD = \sqrt{\frac{\Sigma(Y_1 - Y_{mean})^2}{n}}$$

2. Projected Water Demand Analysis

House Connection Water Demand

The value of SR water demand is influenced by the number of people served and household water consumption in Pecatu Village, where in this projection household water consumption is 120 L / person / day (SNI 19-6728.1-2002).

$$Q_{SR} = House\ Connection\ x\ Population\ Served$$

Domestic Demand

The result of domestic water demand is influenced by the amount of SR water demand and also the demand for public tap water in each village, where in this projection the demand for public tap water is 0 L/day.

$$Q_{Domestic} = Q_{SR} + Q_{KU}$$

Non-Domestic Demand

The result of non-domestic water demand is influenced by domestic water demand in each village, the value will be multiplied by 20% where 20% is the percentage value of non-domestic demand.

$$Q_{Non\ Domestic} = 20\%\ x\ Q_{Domestic}$$

Total Demand

The value of total water demand is influenced by domestic water demand and non-domestic water demand in each village.$Q_{Total\ (L/hari)} = Q_{Domestik} + Q_{Non\ Domestik}$

$$Q_{Total\ (L/sec)} = \frac{Q_{Domestic} + Q_{Non\ Domestic}}{86400}$$

Water Loss

The value of the amount of water loss is obtained from multiplying the % water loss and total demand. Where usually the % water loss ranges from 10%-20%, so in this projection it uses 20% for % water loss.

$$Water\ Loss\ Total = 20\%\ x\ Q_{Total}$$

Average Water Demand

The average water demand usage value can be obtained by summing the total water demand and the amount of water loss.

$$Q_{hr} = \text{Total Demand}\left(\frac{\text{L}}{\text{sec}}\right) + \text{Water Loss Total}$$

Maximum Water Demand

The maximum demand depends on the maximum day factor (Fhm) whose value is in the range of 1.1 - 1.5. Fhm is influenced by the size of the city, which shows a greater value of Fhm than a small city. Climate, which affects the high and low difference in water usage on maximum days and weekdays.

$$Q_{hm} = F_{hm}\ x\ Q_{hr}$$

Peak Hour Demand

The largest water usage in 1 hour in the span of 1 day. This can occur due to simultaneous use at one time. This depends on the peak hour factor which is in the range of 1.15 - 3.

$$Q_{jp} = F_{jp}\ x\ Q_{hm}$$

C. Hydraulic Analysis of Piping Network

1. Pipe Dimension Calculation

Calculation of pipe dimensions can be done using the Hazen William equation, which is as follows:

$$Q = 0{,}2785 \text{ x C x } D^{2,63} \text{ x } S^{0,54}$$

The Hazen Williams pipe roughness coefficient is as follows:

Tabel 1. Hazen Williams Coefficient of Roughness *(*Source: Epanet 2 user manual)

No.	Pipe Type	C Value
1	New Cast Iron	130 - 140
2	Concrete or Concrete lined	120 - 140
3	Galvanized Iron	120
4	Plastic	140 - 150
5	Stell	140 - 150
6	Vetrivied Clay	110

2. Water Pressure and Flow Velocity

The optimal amount of water pressure ranges over a fairly wide area and depends on the usage requirements and the equipment to be served. Generally, it can be said that the standard pressure is 1.0 kg/cm2, while the static pressure should be between 4.0-5.0 kg/cm2 for offices and 2.5-3.5 kg/cm2 for hotels and housing. If the water flow velocity is too high, it will increase the possibility of water blows, make noise and sometimes cause damage to the surface inside the pipe. Usually a standard speed of 0.6-1.2 m/s is used, and the maximum limit is 1.5-2.0 m/s. Meanwhile, speeds that are too low can also cause corrosion effects, deposition of dirt that can affect water quality.

3. Loss of Pressure

Major losses

Major losses are due to water friction against the pipe wall. The amount of pressure loss by friction can be obtained by the general formula of Darcy, namely:

$$hf = 8x\frac{L}{D^S}.\frac{Q^2}{\pi^2 g} \text{ atau } hf = fx\frac{L}{D}.\frac{V^2}{2g}$$

Minor Losses

Minor losses are formed due to changes in the cross-section of pipes, joints, turns, and valves. Sudden and gradual changes in cross-section or turns can minimize secondary power losses. Minor losses equation:

$$hf = k\frac{V^2}{2g} \text{ atau } hf = k\frac{Q^2}{2A^2 g}$$

D. Support Building Analysis

1. Analysis of Reservoir Requirement

In planning the installation of the main pipe, it is necessary to calculate or analyze the capacity and dimensions of the reservoir. The reservoir capacity is the volume of the reservoir, while the reservoir dimensions consist of the length, width, and height of the reservoir.

a. Reservoir Capacity Calculation

The calculation of reservoir capacity or volume can be done using the following formula.

$$v = \frac{20\% \times 24 \times 3.600 \times K}{1.000(\frac{m3}{liter})}$$

b. Reservoir Dimension Calculation

The calculation of reservoir dimensions which include the length, width, and height of the reservoir can be done using the following formula.

$$v = \frac{A}{t}$$

$$P = \sqrt{A}$$

$$L = \frac{A}{P}$$

2. Pipe Accessories Needs

In the transmission pipeline network, there are pipe accessories consisting of air valves, gate valves, and wash outs.

a. Air Valve

Air valve is an air valve that is used to reduce the pressure in the pipe so that the pipe does not break [14].

b. Gate Valve

Gate valve is a valve that is used to open and close the flow (stop valve) which is not too high. The gate valve also functions as a flow discharge controller when there is a change in flow direction. In the distribution of clean water, the gate valve is placed at the fork of the pipe.

c. Wash Out

Wash out or drain pipe serves to drain sediment or sediment in the distribution pipe [14]. Wash out is installed in places with relatively low elevation along the pipeline.

3. RESULT AND DISCUSSION

A. Water Demand Analysis

1. Pecatu Village Population Projections

In this calculation, the population projection of Pecatu Village is made for a period of 12 years from 2012 to 2023.

Table 2. Pecatu Village Population Growth Projections

Year	People	Growth	% Growth	Arithmetic	Geometrics	*Least square*
2017	7904	0	0	7904	7923	52381
2018	7989	85	1.06	7993	8006	50897
2019	8196	207	2.53	8083	8090	49413
2020	7884	-312	-3.96	8172	8175	47928
2021	8261	377	4.56	8261	8261	46444
JUMLAH		357	4.2			
RATA-RATA		89.25	1.05			
Standar Deviasi (SD)				131.17	127.41	105.48

Source: Analysis Result

Based on the calculation of the Standard Deviation (SD) of each method, the smallest SD is the Least square method, where the SD is 105.48. Therefore, the Least square method is considered the most effective in calculating the population projection of Pecatu Village for the next 10 years.

Based on the calculation of population projections that have been carried out, the following are the results of population projections in Pecatu Village until 2033 using the Least square method as the most effective method. It can be concluded that the total population of Pecatu Village projected until 2033 is 8839 people.

Table 3. Pecatu Village Population Projection Results until 2033

Year	Total Population
2022	8169
2023	8230
2024	8290
2025	8351
2026	8412
2027	8473
2028	8534
2029	8595
2030	8656
2031	8717
2032	8778
2033	8839

Source: Analysis Result

2. Projection Water Demand
   Berikut merupakan tabel perhitungan analisis kebutuhan air minum secara keseluruhan.

Table 4. Pecatu Village Drinking Water Demand Projection

PECATU VILLAGE DRINKING WATER DEMAND PROJECTION		
Description	Unit	Data Projection Year 2023
A. Population		
Total Population		8839
Level of Service		100%
Population Served		8839
B. Kebutuhan Domestik		
House Connection	L/day	120
KU		
Water Demand SR		1060680
Water Demand KU		
Domestic Demand	L/day	1060680
C. Non Domestic Demand		
20% Domestic Served	L/day	212136
D. Total Water Demand		
	L/day	1272816
	L/sec	14.732

E. Water Loss		
% Water Loss		20%
Total Water Loss	L/sec	2.946
F. Water Demand Average		
Total Water Demand	L/sec	17.678
G. Maksimum Day Demand		
Coefisien Factor		(1,2-2)
Water Demand	L/sec	22.10
H. Peak Hour Demand		
Coefisien Factor		2
Kebutuhan Air	L/sec	44.195

Source: Analysis Result

Based on the analysis results contained in table 4, it is found that the maximum day demand of Pecatu Village is 22.10 L/s, the average water demand is 17.678 L/s, the peak hour demand is 44.195 L/s and the water loss is 2.946 L/s.

B. Hydraulic Analysis of Piping Networks

1. Hydraulic Profile of Main Pipe Plan

In planning the installation of the main pipe in Pecatu Village, the hydraulic profile of the elevation of the main pipe plan in Pecatu Village is made into 4 segments. The main pipe line is made based on the classification of public roads based on its function. The grouping of public roads according to their function includes Arterial Roads, Collector Roads, Local Roads and Neighborhood Roads [15].

- Segment 1: Elevation of the main pipeline from the reservoir to Jalan Raya Uluwatu. Its length is 2,232 m. Segment 1 belongs to the Collector Road group.
- Segment 2: Elevation of the main pipeline of Jalan Raya Uluwatu-Jalan Labuansait. The length is 7,605 m. Segment 2 belongs to the Local Road group.
- Segment 3: Elevation of the main pipeline Jalan Raya Uluwatu-Jalan Batu Kandik. Its length is 4,969 m. Segment 3 belongs to the Local Road group.
- Segment 4: Elevation of the main pipeline Jalan Raya Uluwatu-Jalan Raya Uluwatu. The length is 3,554 m. Segment 4 belongs to the Collector Road group.

2. Calculation of Plan Pipe Diameter

Based on the calculation results with the Hazen William equation, the size of the pipe plan as follows:

Table 5. Diameter Planning Pipe (Source: Analysis)

Segmen Pipa	Diameter (inch)

Reservoir - Jalan Raya Uluwatu ➔ SEGMEN 1	8
Jalan Raya Uluwatu – Jl. Labuan Sait ➔ SEGMEN 2	6
Jalan Raya Uluwatu – Jalan Batu Kandik ➔ SEGMEN 3	6
Jalan Raya Uluwatu – Jalan Raya Uluwatu ➔ SEGMEN 4	6

The planned main pipe diameter obtained above is the result of calculations with consideration of the location elevation factor, pipe length, pressure difference, discharge, and conveyance speed. Another major factor in obtaining the above pipe diameter data is the projected drinking water demand in Pecatu Village until 2033.

C. Analysis of Support Building

1. Analysis of Reservoir Capacity

   Reservoir capacity is obtained based on the maximum day demand in Pecatu Village, namely the maximum day demand of 22,098 l/sec, so that the transmission reservoir volume is 381,845 m3.

   Then, the dimensions of the transmission reservoir can be concluded:

   Reservoir Lenght (p) = 7 m
   Reservoir Width (l) = 7 m
   Reservoir Height = 10 m

2. Pipe Accessories Requirement

   The uses of these pipe accessories are as follows.

   a. Pipe Plan from the reservoir to Uluwatu Street
   - Air Valve : 4 pcs
   - Bend 45 : 1 pcs

   b. Pipe Plan from Uluwatu Street – Labuansait Street
   - Air Valve : 3 pcs
   - Bend 45 : 19 pcs
   - Gate Valve : 1 pcs

   c. Pipe Plan from Uluwatu Street – Batu Kandik Street
   - Air Valve : 3 pcs
   - Bend 45 : 15 pcs
   - Gate Valve : 1 pcs

   d. Pipe Plan from Uluwatu Street – Uluwatu Street
   - Air Valve : 3 pcs
   - Bend 45 : 5 pcs
   - Gate Valve : 1 pcs

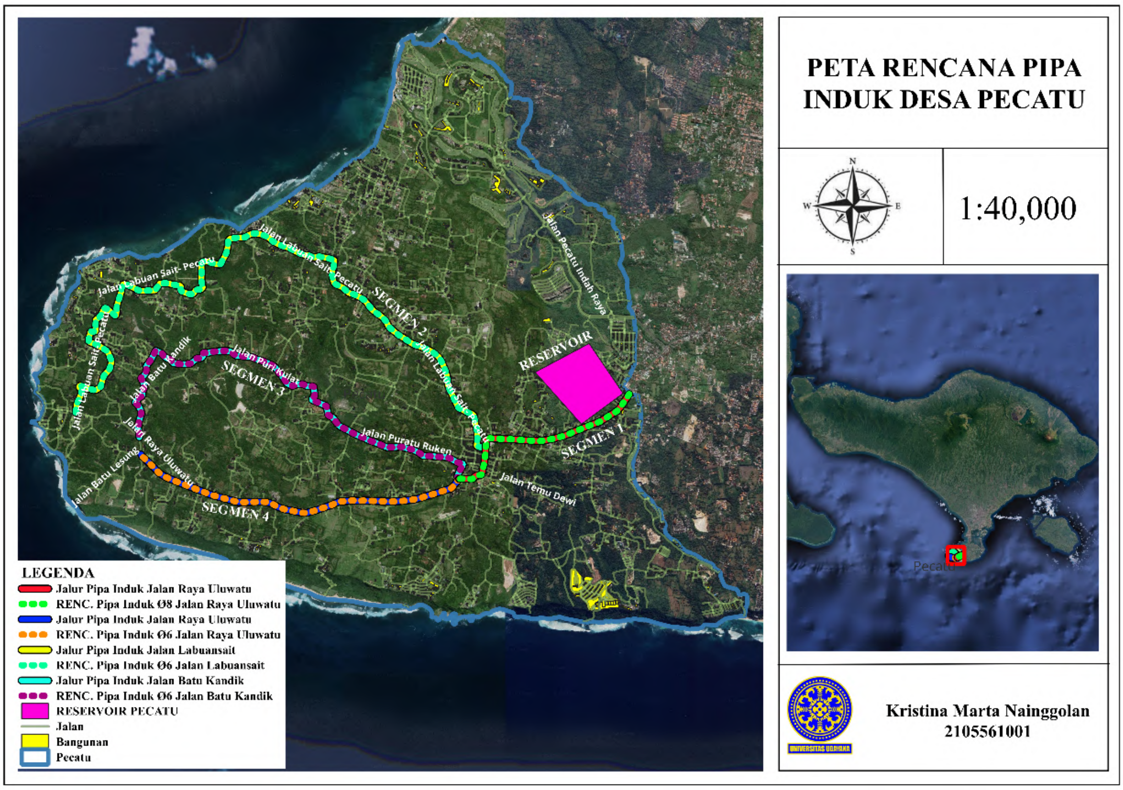

Figure 2. Map of Planning Master Pipe Pecatu Village

4. CONCLUSION

Based on the analysis conducted with population projections using the Least Square method, it is found that the population of Pecatu Village in 2033 is 8839 people with a maximum day demand of 22.10 L / sec, which is where the reservoir capacity of Pecatu Village is 381,845 m^3. The main pipe is planned on three main roads in Pecatu Village, namely Jalan Raya Uluwatu, Jalan Labuansait, Jalan Batu Kandik. From the calculation results, it is obtained that the main pipe size that will distribute water optimally is Ø6 inch pipe and Ø8 inch pipe.

5. ACKNOWLEDGMENTS

Thank you to all those who have helped write this journal to completion. Hopefully this journal can be used properly by those who need it.

DAFTAR PUSTAKA

[1] M. T. H. van Vliet *et al.*, "Global water scarcity including surface water quality and expansions of clean water technologies," *Environ. Res. Lett.*, vol. 16, no. 2, 2021, doi: 10.1088/1748-9326/abbfc3.

[2] V. A. Tzanakakis, N. V. Paranychianakis, and A. N. Angelakis, "Water supply and water scarcity," *Water (Switzerland)*, vol. 12, no. 9. 2020. doi: 10.3390/w12092347.

[3] P. N. Cahyo, M. P. Hadi, and T. N. Adji, "Pengaruh Potensial Sourcedaya Air terhadap Penggunaan Kebutuhan Domestik di Kecamatan Eromoko Kabupaten Wonogiri," *Maj. Geogr. Indones.*, vol. 30, no. 2, pp. 196–206, 2016, [Online]. Available: https://jurnal.ugm.ac.id/mgi/article/view/15649/10438

[4] I. M. Satya G. and A. A. Ratu R. W., "Analisis Kebutuhan Air Bersih Di Wilayah Kecamatan Kuta Dan Kuta Selatan Kabupaten Badung," *J. Ganec Swara*, vol. 17, no. 2, pp. 624–630, 2023, [Online]. Available: http://journal.unmasmataram.ac.id/index.php/GARA

[5] K. N. Saputri, "Relasi Bisnis dan Politik: Studi Kasus Gejala Krisis Air Bersih di Badung Selatan, Bali," *J. Int. Relations Univ. Diponegoro*, vol. 3, no. 3, pp. 29–37, Jul. 2017, doi: 10.14710/JIRUD.V3I3.16797.

[6] I. K. A. Manuartha, D. Pascarani, and E. Purnamaningsih, "Evaluasi Pelayanan Perusahaan aerah Air Minum (PDAM) Tirta Manguntama alam Peningkatan Kepuasan Pelanggan(Studi Kasus Kecamatan Kuta Selatan Kabupaten Badung)," *J. Akad.*, vol. 01, no. 01, pp. 1–15, 2016, [Online]. Available: https://ojs.unud.ac.id/index.php/citizen/article/view/20093

[7] Kementerian Pekerjaan Umum dan Perumahan Rakyat, *Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat Nomor 27 Tahun 2016 Tentang Penyelenggaraan Sistem Penyediaan Air Minum*, vol. 27. 2016, pp. 1–41. [Online]. Available: https://peraturan.bpk.go.id/Download/136665/Permen PUPR Nomor 27 Tahun 2016.pdf

[8] Republik Indonesia, *Peraturan Pemerintah Republik Indonesia Nomor 122 Tahun 2015 Tentang Sistem Penyediaan Air Minum*, vol. 2015, no. 122. Indonesia, 2015, pp. 1–239. [Online]. Available: https://peraturan.bpk.go.id/Download/28467/PP Nomor 122 Tahun 2015.pdf

[9] Hamdani, H. Sulistio, and Z. Syahputra, "PERENCANAAN PIPA DISTRIBUSI AIR BERSIH KELURAHAN SAMBALIUNG KECAMATAN SAMBALIUNG KABUPATEN BERAU," *J. Keilmuan dan Apl. Tek. Sipil*, vol. 4, no. 1, pp. 178–186, Nov. 2014, Accessed: Jan. 28, 2024. [Online]. Available: http://ejurnal.untag-smd.ac.id/index.php/TEK/article/view/844

[10] R. Haqiqi, "Perencanaan Sistem Transmisi dan Distribusi Air Minum Source Mata Air Wae Decer Kabupaten Manggarai," Universitas Islam Negeri Sunan Ampel, 2019.

[11] D. Putra, R. I. Hapsari, and M. Efendi, "Perencanaan Jaringan Pipa Transmisi dan Distribusi Air Bersih Kecamatan Tegalsiwalan Kabupaten Probolinggo," *J. Online Skripsi Manaj. ...*, vol. 3, no. 1, pp. 26–32, 2022, [Online]. Available: http://jurnal.polinema.ac.id/index.php/jos-mrk/article/view/1035%0Ahttp://jurnal.polinema.ac.id/index.php/jos-

mrk/article/download/1035/753

[12] M. Noor, W. Harsanti, and R. I. Hapsari, "Perencanaan Jaringan Pipa Transmisi dan Distribusi Air Bersih Kecamatan Tugu Kabupaten Trenggalek," *J. Online Skripsi*, vol. 3, no. 2, pp. 48–53, 2022, [Online]. Available: http://jurnal.polinema.ac.id/index.php/jos-mrk/article/view/1035%0Ahttp://jurnal.polinema.ac.id/index.php/jos-mrk/article/download/1035/753

[13] B. D. M. Amalia Intan Sari, "Perencanaan Peningkatan Sistem Distribusi Air Minum Source Mata Air Umbulan di Wilayah Pelayanan Offtake Waru Kabupaten Sidoarjo," *J. Tek. Pomits*, vol. 2, no. 1, pp. 10–13, 2013.

[14] A. Kurniawan, A. Priyanto, S. Suripin, and S. Salamun, "Perencanaan Sistem Penyediaan Air Bersih PDAM Kota Salatiga," *J. Karya Tek. Sipil*, vol. 3, no. 4, pp. 985–994, 2014, [Online]. Available: http://ejournal-s1.undip.ac.id/index.php/jkts

[15] Republik Indonesia, *Undang-Undang Republik Indonesia Nomor 38 Tahun 2004 Tentang Jalan*. Indonesia, 2004, pp. 1–43. [Online]. Available: https://peraturan.bpk.go.id/Download/30523/UU Nomor 38 Tahun 2004.pdf