STUDY ON THE OPTIMUM FLUSHING VOLUME OF THE SEWER SYSTEM IN SOUTH TANGERANG CITY

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ABSTRACT

**Aims:** This planning aims to obtain the optimum flush volume on the design of sewerage in South Tangerang City. 

**Methodology and results:** Factors affecting this flushing are the length of pipelines, the service area, and topographic conditions. The sewer drain that needs flushing is Line 1–WWTP since the minimum velocity is not eligible due to its relatively low average topographic slope. The flushing is required particularly for the Section 1–2. Hence, two alternatives were devised by dividing the Population Equivalent (PE) in Section 1–2 into three segments. Those alternatives were differentiated by the PE—20%, 5%, and 75% for Alternative 1; whereas 10%, 15%, and 75% for Alternative 2. Alternative 1 requires flushing on Section 1–1.1 since it has a \(d_{min}\) of 7 cm and \(v_{min}\) of 0.2585 m/s, yielding a flush volume of 3.94 m\(^3\) (0.0193 m\(^3\)/s). Section 1.1–1.2 still needs flushing because this channel has a \(v_{min}\) of 0.4281 m/s and a qualified \(d_{min}\) of 15 cm, generating a flush volume of 7.89 m\(^3\) (0.2113 m\(^3\)/s). Flushing is not necessary for Section 1.2–2 due to its sufficient \(d_{min}\) of 63 cm and \(v_{min}\) of 0.88 m/s. Alternative 2 requires flushing on Section 1–1.1 since it has a \(d_{min}\) of 7 cm and a \(v_{min}\) of 0.2585 m/s, resulting in a flush volume of 2.63 m\(^3\) (0.0193 m\(^3\)/s). Section 1.1–1.2 still requires flushing on account of its \(v_{min}\) of 0.3877 m/s and the yielded flush volume of 18.4 m\(^3\) (0.2625 m\(^3\)/s), though its \(d_{min}\) of 13 cm complies with the standard. Section 1.2–2 does not need flushing as it already has a \(d_{min}\) of 63 cm and a \(v_{min}\) of 0.88 m/s. The total flush volumes for Alternative 1 and Alternative 2 are 11.83 m\(^3\) and 21.04 m\(^3\), respectively.

**Conclusion, significance, and impact of the study:** The total flush volume for Alternative 1 is 11.83 m\(^3\), while Alternative 2 is 21.04 m\(^3\). Thus, the optimum design having the least flush volume is Alternative 1.
1. INTRODUCTION

South Tangerang City is one of the regions that serve as the buffer for DKI Jakarta and grow rapidly. Currently, South Tangerang City has a unit of Wastewater Treatment Plant (WWTP) located in the Techno Park industrial area, Setu Subdistrict, that specifically serves the needs of the industries within the area. On the other hand, household wastewater management in South Tangerang City is quite poor at this time, as grey water derived from the domestic activities are discharged directly into drainage channels. Therefore, it is highly necessary to devise a proper sewer system for a better sanitation system.

The sewerage plan of South Tangerang City is designed until 2037 with approximately projected population of 2,327,596 people. The service coverage in this facility plan is 100%, comprising 581,899 house connections, while the wastewater flow rate is 3,702.0441 L/sec. The designed length of the main sewer drain is 37,358 m long with a diameter of 500 mm to 2,100 mm.

The highest elevation throughout South Tangerang City is in Pamulang Sub district of 50–62.5 meters above sea level (MASL); whereas Setu, Serpong, Ciputat, and East Ciputat have an elevation of 37.5–50 MASL. The lowest elevation is pinpointed in Pondok Aren and North Serpong sub districts of <25 MASL. The trend of the topographic slope in South Tangerang City leads to North Serpong Sub district which has the lowest elevation.

The wastewater of South Tangerang City is planned to stream down to one WWTP which has a flow rate of 3,702.0441 L/sec, located in Paku Alam, North Serpong Sub district. The elevation of this WWTP is 23 MASL. The master plan of main sewer drains can be seen in Figure 1.

There are five paths to WWTP in this planning of South Tangerang City sewer system, i.e., Line 1–WWTP, Line 2–WWTP, Line 3–WWTP, Line 4–WWTP, and Line 5–WWTP, as shown in Figure 1. Each of these pathways has a different topographic slope. The average topographic slope of those five lines from their starting points to the plant is 0.00088, 0.00221, 0.00284, 0.00429, and 0.00368, respectively. Among all the five routes, Line 1–WWTP—as seen in Figure 2—has the lowest topographic slope. It results in the ineligibility of both minimum velocity ($v_{min}$) (<0.6 m/sec) and minimum depth ($d_{min}$) (<10 cm).
Line 1–WWTP requires flushing on the Section 1–2 due to its low $v_{\text{min}}$ of 0.5004 m/sec (less than 0.6 m/sec), though its $d_{\text{min}}$ of 19 cm has already met the standard. This ineligible minimum velocity is induced by the relatively low value of the average topographic slope in Line 1–WWTP (0.00088). Profiles of the topographic slope and the pipe slant are depicted in the longitudinal section of Line 1–WWTP (Figure 3).

This article will discuss the calculation of flush volume and flow rate for the sewerage planning of South Tangerang City. Two alternatives were compared in this study to determine the optimum one based on the flush volume and flow rate.
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Figure 2 Line 1 – WWTP

Figure 3 Longitudinal section of line 1 – WWTP

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2. RESEARCH METHODOLOGY

2.1 Materials

Both alternatives were differentiated based on their service coverage and flow rates. The sewer that needs flushing is Section 1 - 2. At Point 1, the service area is Block A - which then the Population Equivalent (PE) was divided into 20%, 5%, and 75% for Alternative 1. The former length of Section 1–2 of 1,340 m was divided into three sections, i.e., Section 1 - 1.1 (251.25 m), Section 1.1–1.2(83.75 m), and Section 1.2 - 2 (1,005 m). The determination of manhole placements was based on the South Tangerang City roadmap. Manholes were established near secondary roads to ensure their convenient connections to the lateral pipes. For Alternative 2, the Population Equivalent (PE) for Block A was divided into 10%, 15%, and 75% with the former length was divided into three sections, i.e., Section 1 - 1.1 (167.5 m), Section 1.1 - 1.2 (167.5 m), and Section 1.2–2 (1,005 m).

2.2 Methods

The planning procedure is shown in Figure 4. The method used in this calculation is open-channel hydraulics for partially full pipe flow. The graph of Design of Main Sewers (Fair et al., 1966) was used to facilitate this calculation.

2.2.1 Analytical Method

The analytical methods shown in this study are as follows

a. Determining \(d_{\text{min}}\) and \(v_{\text{min}}\)

Determining \(d_{\text{min}}/d_{\text{full}}\) and \(v_{\text{min}}/v_{\text{full}}\) was carried out by using Design of Main Sewers graph, preceded by the calculation of \(Q_{\text{min}}/Q_{\text{full}}\).
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Figure 4 Flowchart of the planning method
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b. Calculating \( vw \)

\[
VW = V_{\text{min}} + \sqrt{\frac{g(\text{Af}.\text{df}) - (\text{Amin}/\text{dmin})}{\text{A min}(1 - \text{Amin}/\text{Af})}}
\]  

\( vw \): wave velocity; \( g \): gravity acceleration (9.81 m/s\(^2\)); \( \text{Af} \): flush area (m\(^2\)); \( \text{df} \): flush depth (m); \( \text{A min} \): minimum area (m\(^2\)); \( \text{d min} \): minimum depth (m)

c. Calculating the flush volume (\( Vf \))

\[
Vf = Lx (\text{Af} - \text{A min})
\]  

\( Vf \): flush velocity (m/s); \( L \): pipe length (m); \( \text{Af} \): flush area (m\(^2\)); \( \text{A min} \): minimum area (m\(^2\))

d. Calculating the flush flow rate (\( Qf \))

\[
Qg = VW \times (\text{Af} - \text{A min})
\]  

\( Qg \): flush flow rate (m\(^3\)/s); \( VW \): wave velocity; \( \text{Af} \): flush area (m\(^2\)); \( \text{A min} \): minimum area (m\(^2\))

3. RESULTS AND DISCUSSION

The length of pipelines and the service coverage in the preliminary design are still quite large, inducing a high wastewater flow rate. Consequently, the flush volume is increased. The topographic conditions of South Tangerang City also contribute to this flush volume increment. Accordingly, the design modifications of Alternative 1 and Alternative 2 have been devised to minimize the flush volume and flow rate by reducing the length of sewer lines as well as the service coverage.

In this planning, flushing is required on line 1, Section 1–2. Hence, two manholes were added to this route and the service area was segmented into 5%, 20%, and 75% of Population Equivalent (PE). The determination of these percentages were based on the South Tangerang City roadmap. These PEs were divided based on the topographic conditions in South Tangerang City. So the wastewater could flow to the sewer system. Section 1–2 of Alternative 1 and its longitudinal section are shown in Figure 5 and Figure 6, respectively.
Figure 5 Section 1–2 of alternative 1

Figure 6 Longitudinal section of section 1–2 of alternative 1
Subsequent to the segmentation of Section 1 - 2, calculations to obtain the minimum flow rate \( (Q_{\text{min}}) \) for each segment were carried out. The minimum flow rate for Section 1 - 1.1 equals 7.62 L/sec, while for Section 1.1 - 1.2 is 9.96 L/sec and for Section 1.2 - 2 is 52.59 L/sec.

The pipe diameter of Section 1–1.1, Section 1.1–1.2, and Section 1.2 - 2 is 1,000 mm with a slope of 0.0007 each. Flushing is necessary if the minimum depth \( (d_{\text{min}}) \) is less than 10 cm and the minimum velocity \( (v_{\text{min}}) \) is < 0.6 m/sec. Flushing is required for Section 1 - 1.1 due to its ineligible depth \( (d_{\text{min}}) \) of 7 cm (less than 10 cm). Likewise, the minimum velocity \( (v_{\text{min}}) \) in this section of only 0.2585 m/sec does not meet the standard of 0.6 m/sec as well. The computation of flush volume for Section 1 - 1.1 was conducted afterward, generating a value of 3.94 m\(^3\) with a flow rate of 0.0193 m\(^3\)/sec.

Following the flushing on Section 1 - 1.1, the minimum flow rate of the next pathway was added up to the flush flow rate. However, the minimum velocity in Section 1.1 - 1.2 of 0.4281 m/sec could not comply with the standard, though its minimum depth of 15 cm has been considered as eligible. Therefore, the flushing is needed for Section 1.1 - 1.2. The obtained flush volume for this section is 7.89 m\(^3\) with a flow rate of 0.2113 m\(^3\)/sec. The minimum flow rate of Section 1.2 - 2 was then added up to the flush flow rate.

The results of both the minimum depth and the minimum velocity on Section 1.2 - 2 of 63 cm and 0.88 m/sec, respectively, have met the specified criteria. In summary, the flush volume required for Line 1 - WWTP of Alternative 1 is 11.83 m\(^3\). The detailed calculation can be seen in Table 1 and Table 2.
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Tabel 1 Calculation of flushing determination for alternative 1

| Pipeline | Pipe length (m) | Q_min (m³/sec) | Q_full (m³/sec) | Q / Q_full | d_min / d_full | D_d (mm) | v_min (mm) | v full (mm) |
|----------|----------------|----------------|-----------------|-------------|---------------|----------|------------|------------|
| 1–1.1    | 251.25         | 0.00762        | 0.63402         | 0.01        | 0.07          | 1.00     | 70         | 0.32       |
| 1.1–1.2  | 83.75          | 0.00996        | 0.63402         | 0.05        | 0.15          | 1.00     | 150        | 0.53       |
| 1.2–2    | 1,005          | 0.05259        | 0.63402         | 0.45        | 0.63          | 1.00     | 630        | 1.09       |
| 2–3      | 2,230          | 0.16311        | 1.24473         | 0.32        | 0.42          | 1.40     | 588        | 0.93       |
| 3–4      | 1,760          | 0.25540        | 1.66254         | 0.29        | 0.39          | 1.40     | 546        | 0.89       |
| 4–5      | 2,443          | 0.31588        | 1.84310         | 0.30        | 0.39          | 1.650    | 643.5      | 0.89       |
| 5–6      | 2,420          | 2.35462        | 7.14544         | 0.36        | 0.42          | 2.100    | 882        | 0.93       |
| 6–7      | 910            | 2.54908        | 7.55407         | 0.37        | 0.42          | 2.100    | 882        | 0.93       |
| 7–8      | 945            | 2.66024        | 7.75032         | 0.37        | 0.43          | 2.100    | 903        | 0.93       |
| 8–WWTP   | 385            | 3.48607        | 9.33262         | 0.40        | 0.44          | 2.100    | 924        | 0.94       |

Similar procedures were performed on Alternative 2. Two manholes were added to this route and the service area was segmented into 10%, 15%, and 75% of Population Equivalent (PE). Figure 7 shows the scheme of Section 1 - 2, whereas Figure 8 represents its longitudinal section. The minimum flow rates for Section 1 – 1.1, Section 1.1 – 1.2, Section 1.2 – 2 are 3.32 L/sec, 9.96 L/sec, and 52.59 L/sec, respectively.

The sewer diameter of Section 1 - 1.1, Section 1.1 - 1.2, and Section 1.2 - 2 is 1,000 mm with a pipe slope of 0.0007 each. The same term of flushing was applied to this alternative - it is performed if the minimum depth ($d_{min}$) is less than 10 cm and the minimum velocity ($v_{min}$) is less than 0.6 m/sec. Section 1 - 1.1 requires flushing since its minimum depth ($d_{min}$) of only 7 cm does not comply with the 10 cm standard. Likewise, its minimum velocity ($v_{min}$) of 0.2585 m/sec is not qualified as well (<0.6 m/sec). Calculations of flush volume and flow rate were then executed based upon this flushing determination for Section 1 - 1.1, generating values of 2.63 m³ and 0.0193 m³/sec.
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Figure 7 Section 1–2 of alternative 2

Figure 8 Longitudinal section of section 1 - 2 of alternative 2
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Table 3 Calculation of flushing determination for alternative 2

| Pipeline | Pipe length (m) | Q min (m³/sec) | Q full (m³/sec) | Q full / Q full | d min (mm) | v min / v full | v full (m³/sec) | < 0.6 m/sec |
|----------|----------------|----------------|----------------|----------------|------------|---------------|----------------|------------|
| 1−1.1    | 167.5          | 0.0033         | 0.6340         | 0.0052         | 0.07       | 1.00          | 0.32           | 0.2585     |
| 1.1−1.2  | 167.5          | 0.0100         | 0.6340         | 0.0046         | 0.13       | 1.00          | 0.30           | 0.1877     |
| 1.2−2    | 1,005          | 0.0526         | 0.6340         | 0.0527         | 0.63       | 1.00          | 0.32           | 0.2190     |
| 2−3      | 2,230          | 0.1631         | 1.2447         | 0.3575         | 0.42       | 1.40          | 0.99           | 0.7524     |
| 3−4      | 1,760          | 0.2545         | 1.6625         | 0.3224         | 0.39       | 1.40          | 0.69           | 0.6917     |
| 4−5      | 2,443          | 0.3159         | 1.6431         | 0.3243         | 0.39       | 1.65          | 0.89           | 0.8624     |
| 5−6      | 2,420          | 2.3546         | 7.1454         | 0.3690         | 0.42       | 2.10          | 0.99           | 2.0641     |
| 6−7      | 910            | 2.5491         | 7.5541         | 0.3748         | 0.42       | 2.10          | 0.99           | 2.1821     |
| 7−8      | 945            | 2.6630         | 7.7503         | 0.3798         | 0.43       | 2.10          | 0.93           | 2.2388     |
| 8−WWTP   | 385            | 3.4861         | 9.3226         | 0.4044         | 0.44       | 2.10          | 0.94           | 2.6958     |

Table 4 Calculation of flush volume and flow rate for alternative 2

| Pipeline | df (m) | /d (m) | /d (m) | d min/d full | A min /A full | A full (m²) | A min (m³) | df/D (m) | A/A (m²) | A (m³) | v (m³/sec) | Flush volume (m³) | Q flash (m³/sec) |
|----------|--------|--------|--------|--------------|---------------|-------------|------------|-----------|---------|--------|-------|-------------|------------------|------------------|
| 1−1.1    | 0.1    | 0.028  | 0.04   | 0.07         | 0.03          | 0.785       | 0.02       | 0.05      | 0.04   | 1.23226| 2.62975      | 0.019346         |
| 1.1−1.2  | 0.27   | 0.052  | 0.11   | 0.13         | 0.07          | 0.785       | 0.05       | 0.27      | 0.21   | 0.16   | 2.3883 | 18.4083      | 0.262474         |

Following the flushing on Section 1 - 1.1, the minimum flow rate of the next sewer line was added up to the flush flow rate. Though the minimum depth of Section 1.1 - 1.2 of 13 cm has met the standard, its minimum velocity of 0.3877 m/sec has not. Thus, the flushing is needed for Section 1.1 - 1.2. The obtained flush volume for this section is 18.41 m³ with a flow rate of 0.2625 m³/sec. The minimum flow rate of Section 1.2 - 2 was then added up to the flush flow rate, resulting in the eligible values of minimum depth (63 cm) and minimum velocity (0.88 m/sec). Hence, the flush volume demand for Line 1 - WWTP of Alternative 2 is 21.04 m³. The detailed computation is listed in Table 3 and Table 4. The comparison between the preliminary design and both modifications of Alternative 1 and Alternative 2 can be seen in Table 5 below.

Table 5 Calculation summary for the preliminary design, alternative 1, and alternative 2

|                      | Alternative 1 | Alternative 2 |
|----------------------|---------------|---------------|
| Population Equivalent (PE) | 20%, 5%, 75%  | 10%, 15%, 75% |
| Length of pipelines   | 251.25 m; 83.75 m; 1,005 m | 167.5 m; 167.5 m; 1,005 m |
| Total flush volume    | 11.83 m³     | 21.04 m³     |

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4. CONCLUSION

Among both sewer lines of the sewerage planning of South Tangerang City, Alternative 1 has been selected as the optimum one due to its lower flush volume requirement for Line 1–WWTP, compared with Alternative 2. The flush volume required for Alternative 1 is 11.83 m$^3$, whereas the amount needed for Alternative 2 equals to 21.04 m$^3$, respectively. The best pathway is based upon the least flush volume requirement since it economizes the demand of the pump capacity to deliver the flush water from the tank truck to the flush structure. The lower flush water expense lessens the operational and maintenance costs as well.

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