Review of Changes in the Second Edition of MSMA – On-Site Detention Computation

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This paper reviews the design of On-Site Detention (OSD) using the first and second editions of MSMA, referred to herein as MSMA (2000) and MSMA (2011) respectively. MSMA is the acronym for Manual Saliran Mesra Alam (Urban Stormwater Management Manual for Malaysia), 2000 and 2011, published by the Department of Irrigation & Drainage or Jabatan Pengairan & Saliran (JPS).

INTRODUCTION

The review was based on case studies in Kuala Lumpur, involving an industrial lot and a low density residential development. The magnitudes of the Permissible Site Discharge (PSD) and the Site Storage Requirement (SSR) are computed by the following three approaches and the differences compared using:

- The Swinburne Method in MSMA (2000), where a set of formulas for PSD and SSR are used to compute their values.
- The Approximate Swinburne Method in MSMA (2011) where a set of approximation tables are used to determine the PSD and SSR values.
- The rainfall and discharge data from MSMA (2011), but instead of computing the PSD and SSR using the Approximate Swinburne Method in MSMA (2011), the formulas from the Swinburne Method in MSMA (2000) are used. This is referred to as the Exact Swinburne Method (ESM).

DESIGN OF ON-SITE DETENTION

1. OSD Sizing in MSMA (2000)

In MSMA (2000), the method of estimating Permissible Site Discharge (PSD) and Site Storage Requirement (SSR) is based on the Swinburne Method, developed at the Swinburne University of Technology in Melbourne, Australia. The method uses the Rational Method to calculate site flows and utilises a non-dimensional triangular site hydrograph based on the triangular design storm method as shown in Diagram 1.

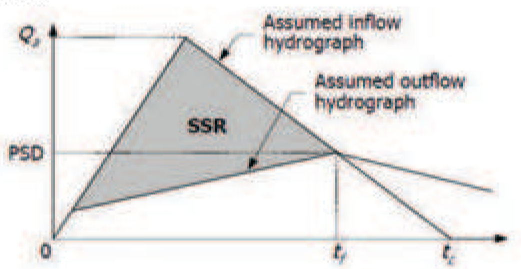


Diagram 1: Swinburne Method Assumptions t_f = Time for Storage to Fill

1.1 Permissible Site Discharge (PSD)

The PSD is the maximum allowable post-development discharge from a site for the selected discharge design storm and is estimated on the basis that flows within the downstream stormwater drainage system will not be increased. The Permissible Site Discharge (PSD) for the site in l/s is given by (Equation 19.1 of MSMA, 2000):

$$PSD = \frac{a - \sqrt{a^2 - 4b}}{2} \qquad (1)$$

The factors a and b are different for above-ground and below-ground storages due to differences in storage geometry and outflow characteristics. For above-ground storage:

$$a = \left(4\frac{Q_a}{t_c}\right)\left(0.333 t_c \frac{Q_p}{Q_a} + 0.75 t_c + 0.25 t_{cs}\right) \qquad (2)$$

$$b = 4 Q_a Q_p \qquad (3)$$

For below-ground storage:

$$a = \left(8.548\frac{Q_a}{t_c}\right)\left(0.333 t_c \frac{Q_p}{Q_a} - 0.35 t_c + 0.65 t_{cs}\right) \qquad (4)$$

$$b = 8.548 Q_a Q_p \qquad (5)$$

where

- t_c is peak flow time of concentration from the top of the catchment to a designated outlet or point of concern (min).
- t_{cs} is peak flow time of concentration from the top of the catchment to the development site (min).
- Q_a is the peak post-development flow from the site for the discharge design storm with a duration equal to t_c (l/s).
- Q_p is the peak pre-development flow from the site for the discharge design storm with a duration equal to t_c (l/s).

1.2 Site Storage Requirement (SSR)

The SSR is the total amount of storage required to ensure that the required PSD is not exceeded and that the OSD facility does not overflow during the storage design storm ARI. The storage design storm for estimating the SSR is 10 -year ARI.

The Site Storage Requirement (SSR) for the site in m³ is calculated using the formula:

$$SSR = 0.06 t_d (Q_d - c - d) \quad (6)$$

The factors c and d are different for above-ground and below-ground storages due to differences in storage geometry and outflow characteristics. For above-ground storage:

$$c = 0.875 * PSD\left(1 - 0.459\frac{PSD}{Q_d}\right) \quad (7)$$

$$d = 0.214\frac{PSD^2}{Q_d} \quad (8)$$

For below-ground storage:

$$c = 0.675 * PSD\left(1 - 0.392\frac{PSD}{Q_d}\right) \quad (9)$$

$$d = 0.117\frac{PSD^2}{Q_d} \quad (10)$$

where
t_d = selected storm duration (min).
Q_d = the peak post-development flow from the site for a storm duration equal to t_d (l/s).

2. OSD Sizing in MSMA (2011)

The steps involved in OSD design in MSMA (2011) are as follows:

1. Select the region from Figure 5.A1 (MSMA, 2011) which divides the peninsula into 5 design regions.
2. Determine project area, terrain steepness, and percentage imperviousness.
3. Determine from Table 5.A1 (MSMA, 2011) the maximum permissible site discharge (PSD) and minimum Site Storage Requirement (SSR) values in accordance with the five regions in Peninsular Malaysia.
4. Then determine, from Table 5.A2 (MSMA, 2011), the maximum permissible site discharge (PSD), minimum Site Storage Requirement (SSR) and inlet values in accordance with the major towns in the peninsula.
5. Adopt smaller PSD value from Table 5.A1 and 5.A2 for subsequent sizing of outlet pipe.
6. Finally, determine the OSD volume, inlet size and outlet size for 5 different regions in the peninsula from Table 5.A3.

CASE STUDIES

1. On-Site Detention for Industrial Land-Use in Kuala Lumpur

This case study concerns the design of a below-ground, on-site detention (OSD) facility based on the guidelines described in MSMA (2000) and MSMA (2011) for a proposed factory lot near SK Taman Maluri, Kuala Lumpur (Figure 1).

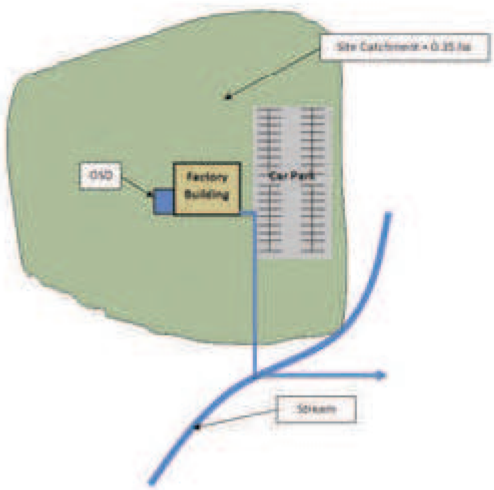


Figure 1: Location of OSD in the Project Site

1.1 OSD in MSMA (2000)

The proposed development of 0.35 hectare consists of a factory lot in an industrial area. Based on Table 4.1 of the manual, the design ARI for minor system discharge for industrial area is 5 years. The design ARI for OSD storage is 10 years according to MSMA (2000). The design rainfall is based on Chapter 13 of the Manual. The design storm for Kuala Lumpur is used in the calculation.

For the purpose of hydrological calculation, it is estimated that 70% of the areas may be considered as impervious. The remaining 30% is assumed pervious. For small catchments of up to 0.4 hectare in area, it is acceptable to use the minimum times of concentration of t_c = 10 min (factory site outlet) and t_{cs} = 5 min (roof and property drainage) as given in Table 14.3 of MSMA (2000).

The peak discharge for ARI = 5 years, is computed using the Rational Method:

$$Q_y = \frac{C \cdot {}^yI_t \cdot A}{360} \qquad (11)$$

where

Q_y is the year ARI peak discharge (m^3/s).

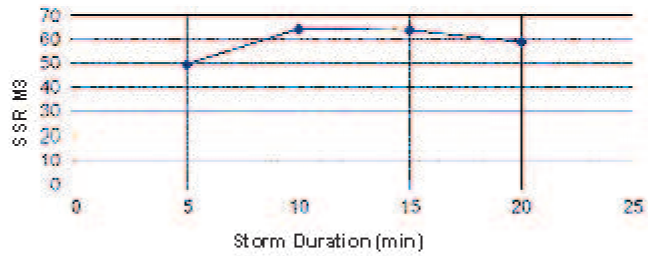
C is the dimensionless runoff coefficient.

${}^yI_t$ is the average intensity of the design rainstorm of duration equal to the time of concentration t_c and of ARI of y year (mm/hr).

A is the drainage area (ha).

Typically, the critical storm duration that produces the largest required storage volume is different from the time of concentration used for peak flow estimation. Therefore, storage volumes must be determined for a range of storm durations to find the maximum storage required.

The SSR values for t_c = 5 to 20 min are plotted as shown in Figure 2. It can be seen that the maximum SSR is 64.3 m^3 for a storm duration of 10 min.



Plot of SSR vs Storm Duration

1.2 OSD in MSMA (2011)

In this section, an OSD is designed using MSMA (2011) for the same site as in the previous section. The project area is located in Kuala Lumpur. From Figure 5.A1 which divides the peninsula into 5 design regions, the project area is located in Region 1 - West Coast. The project area is 0.35 ha. The terrain is mild. The % imperviousness is 70 per cent. Table 5.A1 gives the maximum permissible site discharge (PSD) and minimum Site Storage Requirement (SSR) values in accordance with the five regions. For the project area, SSR = 151.3 m^3. Table 5.A2 gives the maximum permissible site discharge (PSD), minimum Site Storage Requirement (SSR) and inlet values in accordance with the major towns in the peninsula. For the project area, PSD = 0.026 m^3/s. Adopt the PSD value which is the lower from Table 5.A1 and 5.A2 = 0.026 m^3/s. Adopt the SSR that is the larger from Table 5.A1 and 5.A2 = 151.3 m^3.

1.3 Exact Swinburne Method (ESM)

The design rainfall is based on MSMA (2011) for Station No. 4 (SK Taman Maluri). The design ARI for minor system discharge is 10 years for industry as shown in Table 1.1 (MSMA, 2011) and the design ARI for OSD storage is also 10 years according to the manual. The pervious and impervious ratios and the times of concentration adopted are similar to those for MSMA (2000).

In MSMA (2011), the peak discharge is related to the rainfall intensity and catchment area via the Rational Method below:

$$Q = \frac{C \cdot i \cdot A}{360} \qquad (12)$$

where

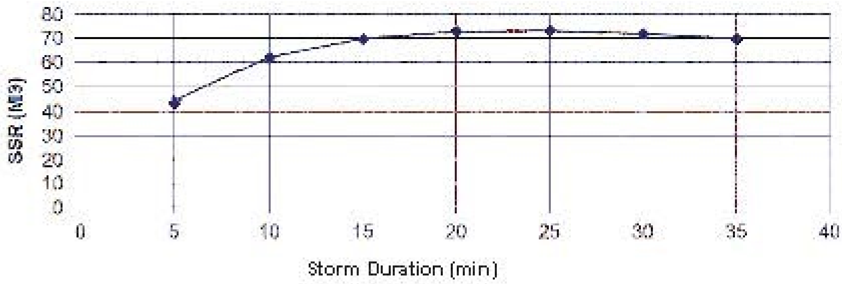
Q is the peak flow (m^3/s).

C is the runoff coefficient given in Table 2.5 of MSMA (2011).

I is the average rainfall intensity (mm/hr).

A is the drainage area (ha).

The SSR for t_c = 5 to 35 mins are plotted as shown in Figure 3. It can be seen that the maximum SSR is 73.2 m^3 for a storm duration of 25 mins.



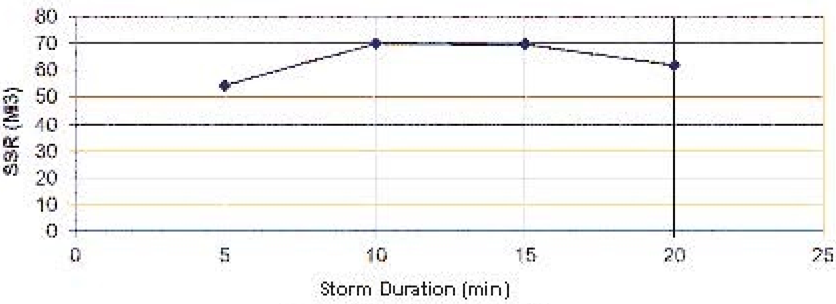
Plot of SSR vs Storm Duration

CASE STUDY OF ON-SITE DETENTION FOR LOW DENSITY RESIDENTIAL LAND-USE IN KUALA LUMPUR

1.1 OSD in MSMA (2000)

This case study concerns the design of a below-ground, on-site detention (OSD) facility using the guidelines described in MSMA (2000) and MSMA (2011) for a low density residential development near SK Taman Maluri, Kuala Lumpur. Based on Table 4.1 of the manual, the design ARI for minor system for low density residential is 2 years. The design ARI for OSD storage is 10 years according to MSMA (2000). The design rainfall is based on Chapter 13 of the Manual. The design storm for Kuala Lumpur is used in the calculation. It is estimated that 70% of the areas may be considered as impervious and 30% impervious. The times of concentration adopted are as follows: t_c = 10 mins and t_{cs} = 5 mins.

The SSR values for tc = 5 to 20 mins are plotted as shown in Figure 2. It can be seen that the maximum SSR is 69.7 m³ for a storm duration of 10 mins.



Plot of SSR vs Storm Duration

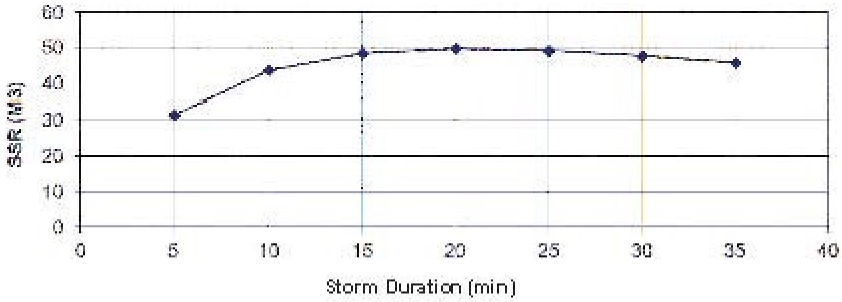
1.2 OSD in MSMA (2011)

The computation for OSD for low density residential development is identical to that for industrial land-use presented in the previous section, as MSMA (2011) does not differentiate between the types of land-use in its computation. Hence the same results apply here.

1.3 Exact Swinburne Method (ESM)

The design rainfall is based on MSMA (2011) for Station No. 4 (SK Taman Maluri). The design ARI for minor system discharge is 5 years for bungalows as shown in Table 1.1 (MSMA, 2011) and the design ARI for OSD storage is 10 years according to the manual. The same pervious and impervious ratios and times of concentration are adopted as before.

The SSR values for t_c = 5 to 35 mins are plotted as shown Figure 5. It can be seen that the maximum SSR is 49.8 m³ for a storm duration of 20 mins.



Plot of SSR vs Storm Duration

EVALUATION

The results of the case studies are evaluated in this section:

1. The approach in MSMA (2011) is based on the Approximate Swinburne Method which is based on approximation tables and not formulas as in the first edition (MSMA, 2000).
2. The result of PSD and SSR for industrial land-use in Kuala Lumpur are summarised in Table 1 for both editions of MSMA. It can be seen that MSMA (2011) gives PSD and SSR of about 0.15 and 2.35 times, respectively, of MSMA (2000).
3. The ESM Method gives PSD and SSR of 0.49 and 1.14 times, respectively, of MSMA (2000) for the site in Kuala Lumpur as shown in Table 1.
4. The result of PSD and SSR for low density residential land-use in Kuala Lumpur are summarised in Table 2. It can be seen that MSMA (2011) gives PSD and SSR of about 0.21 and 2.17 times, respectively, of MSMA (2000).
5. The ESM Method gives PSD and SSR of 0.6 and 0.71 times, respectively, of MSMA (2000) for the same site in Kuala Lumpur as shown in Table 2.

Industry	A	B	C	B/A	C/A
	MSMA 2000	MSMA 2011	ESM		
PSD (L/S)	175.1	26	85.8	0.15	0.49
SSR (M3)	64.3	151.3	73.2	2.35	1.14

Table 1: Comparison of OSD Requirements using MSMA (2000, 2011) for Kuala Lumpur (Industrial)

Bungalow	A	B	C	B/A	C/A
	MSMA 2000	MSMA 2011	ESM		
PSD (L/S)	125.3	26	75.6	0.21	0.60
SSR (M^3)	69.7	151.3	49.8	2.17	0.71

Table 2: Comparison of OSD Requirements using MSMA (2000, 2011) for Kuala Lumpur (Low Density Residential)

6. The results showed that the ESM Method gives a higher estimate of the PSD but a lower estimate of the SSR by using the formulas in Swinburne Method (instead of the Approximate Swinburne Method in MSMA, 2011) and the rainfall and discharge data from MSMA (2011).
7. MSMA (2011) has serious limitations as it cannot be applied outside the 17 major towns in Peninsular Malaysia as listed in Table 5.A2 which gives the maximum permissible site discharge (PSD), minimum Site Storage Requirement (SSR) and inlet values.

8. MSMA (2011) cannot be applied to East Malaysia as Figure 5.A.1 and Table 5.A2 only include major towns in the peninsula.
9. MSMA (2011) does not differentiate between the types of land-usage in its computation of PSD and SSR. Although Table 5.A1 and Table 5.A2 allow varying degree of impervious area, but this is given as a percentage of the project area and does not include areas outside the project area. For example, a factory lot and a bungalow lot may have the same degrees of imperviousness within the project area e.g., 30% in the case studies, but different imperviousness outside. The green fields and playgrounds outside the bungalow lot would significantly increase the permeability of the area. Therefore it is not reasonable to assume the same SSR requirements for industrial and bungalow lots.
10. The ESM Method gives more realistic estimate of SSR than MSMA (2011) as it considers different types of land-usage through the coefficient of runoff in the Rational Formula used to compute the peak discharge and this accounts for the decrease in surface runoff for lands with higher permeability, thus reducing the SSR requirement.
11. The ESM Method may be used outside the 17 major towns in West Malaysia as well as any towns in East Malaysia using local rainfall data.

CONCLUSION

Below are the conclusions from the study carried out in this paper:

1. Reviewed in this paper is the design of On-Site Detention (OSD) using the first and second editions of MSMA. The result shows that for industrial land-use in Kuala Lumpur, the Site Storage Requirement (SSR) using MSMA (2011) is 2.35 times the MSMA (2000) estimate.
2. For low density residential land-use in Kuala Lumpur, the SSR using MSMA (2011) is 2.17 times the MSMA (2000) estimate. The difference is due to the Approximate Swinburne Method used in MSMA (2011), which gives very conservative estimates using approximation tables.
3. The results in the case studies showed that the SSR's estimated using MSMA (2011) for industry lot and low density residential areas are more than double that of MSMA (2000). This over-estimation has far-reaching impact on the entire construction industry and is likely to result in escalating costs.
4. To address the problem of high SSR values associated with the use of MSMA (2011), the Swinburne Method formulas are applied instead of the approximation method in MSMA (2011) using the storm and discharge data of MSMA (2011) to compute the PSD and SSR. The Method is known as the Exact Swinburne Method (ESM).
5. Using this method the SSR using the ESM Method is about 1.14 times that using MSMA (2000) for industrial land-use in Kuala Lumpur. For low density residential land-use in Kuala Lumpur, the ESM Method gives lower estimate of the SSR than MSMA (2000), by about 0.72 times the latter.
6. The ESM Method gives more realistic estimate of SSR than MSMA (2011) as it considers different types of land-usage through the coefficient of runoff in the Rational Formula used to compute the peak discharge and this accounts for the decrease in surface runoff for lands with higher permeability, thus reducing the SSR requirement.
7. The main advantage of ESM Method is it may be used outside the 17 major towns in West Malaysia as well as any towns in East Malaysia using local rainfall data. ■

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Author's Biodata

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