APPLICATION OF BIOECODS FOR A GOVERNMENT COMPLEX: A CASE STUDY

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ABSTRACT

This paper presents an application of Bio-ecological drainage system (BIOECODS) for the proposed forensic wad of Tanjung Rambutan Hospital. BIOECODS is consistent with objectives of new storm water management approach that focus on the control of both the quantity and quality of urban runoff. This has been embodied in the concept of an ecologically sustainable development, which is aimed at ensuring that development can occur without long-term degradation of natural resources and the environment. By integrating storm water management planning with landscape and environmental planning, it will add aesthetic and recreational values to the water amenities.

This new environmental-friendly drainage system adopts “control at source” principle to simulate the natural hydrological cycle in urban areas by combining infiltration, detention storage, delayed flow as well as runoff treatment techniques. BIOECODS comprises grassed swale, detention storage and dry pond components.

The design of the drainage system is based on the new guidelines namely Urban Stormwater Management Manual for Malaysia or MSMA which is published by Department of Irrigation and Drainage (DID) in the year 2000 and gazetted by the government in the following year.

The proposed BIOECODS is an applicable concept as new storm water management approach to minimize the impact of urbanization on the environment. It adopts an integrated approach to obtain both practical and cost effective solutions for drainage system.

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1. INTRODUCTION

In order to realize Vision 2020, Malaysia is moving towards achieving a developed nation status by the year 2020. The Government of Malaysia via the Works Department is planning to construct a new building for the forensic ward of Tanjung Rambutan Hospital on the area of approximately 1.5 hectares in Ipoh, Perak Darul Ridzuan (Figure 1). In this project, the Government is planning to construct a drainage system that shall comply with the new guidelines which is published by Department of Irrigation and Drainage (DID) in the year 2000 and gazetted by the government in the following year, namely Urban Stormwater Management Manual for Malaysia or MSMA.

2. PROJECT BACKGROUND

This project consists of the construction of a single building, which includes administration unit, clinical unit, forensic block and ward. The project covers a catchment area of 1.51 hectares on medium soil type. More than 60% of the total area has been developed into impervious area such as paved road and car park, sheltered walkway, and utilities other than the building. The origin of this area was cultivated field. The pre-development runoff was catered by roadside drain and other existing secondary drains before discharging to the nearest receiving water which is located at 200 meters at the downstream.

3. DESIGN CRITERIA

3.1 Design System

The design criteria for this project was based on Urban Stormwater Management Manual for Malaysia (DID, 2000). The manual recommends a major and minor system approach to be adopted for the planning and design of the proposed drainage system. The minor system is intended to collect and convey runoff from relatively frequent storm events to minimize inconvenience and nuisance flooding. The major system is intended to safely convey runoff not collected by the minor drainage system to waterway or rivers. However, the proposed drainage system for this project was designed to perform as both minor and major system due to the sensitivity of the project and the relatively small coverage area.

3.2 Design Storm

The intensity-duration-frequency (IDF) curves referred in the project are published by the Department of Irrigation and Drainage (DID) in the manual in polynomial expressions for the 35 main cities or towns in Malaysia as given in eq. 1.

\[
\ln(R_I_t) = a + b \ln(t) + c(\ln(t))^2 + d(\ln(t))^3
\]

(1)

where,

- \(R_I_t\) = the average rainfall intensity (mm/hr) for ARI and duration \(t\)
- \(R\) = average return interval (years)
- \(t\) = duration (minutes)
- \(a\) to \(d\) are fitting constants dependent on ARI.
Figure 1 Project Layout.
For duration between 5 and 30 minutes, the design rainfall depth $P_d$ for a short duration $d$ (minutes) is given by,

$$P_d = P_{30} - F_D (P_{60} - P_{30}) \quad (2)$$

where $P_{30}, P_{60}$ are the 30-minute and 60-minute duration rainfall depths respectively, obtained from the published design curves. $F_D$ is the adjustment factor for storm duration.

The rainfall intensity for short duration storms is given by,

$$I = \frac{P_d}{d} \quad (3)$$

where $P_d$ (mm) is rainfall depth in mm and $d$ is duration in hours.

### 3.3 Runoff Estimation

The Rational Formula is one of the most frequently used urban hydrology methods in Malaysia to computing stormwater flows from rainfall. It gives satisfactory results for small catchments up to 80 hectares only.

The formula is:

$$Q_y = \frac{C \cdot \gamma I_t \cdot A}{360} \quad (4)$$

where,

- $Q_y = y$ year ARI peak flow (m$^3$/s)
- $C = \text{dimensionless runoff coefficient}$
- $\gamma I_t = y$ year ARI average rainfall intensity over time of concentration, $t_c$, (mm/hr)
- $A = \text{drainage area (ha)}$

### 3.4 Runoff Conveyance

Grassed swale performs as a conveyance to serve the post-development runoff generated from the developed catchment area. The grassed swale is defined as grass earth channel combined with subsurface modules which enclosed within a permeable geotextile. The grassed swale acts as main conveyor on collecting and discharging runoff while the subsurface module acts as water quality treatment facility and assist in dewatering the base of grassed swale.

The edge of a grassed swale is located 0.5m from road reserve or property boundary. The maximum depth of flow is designed not exceed 500mm with a minimum freeboard of 50mm above the design storm water level in the grassed swale. The average flow velocity is limited to 2m/s. The side slope of grassed swale is 1:4 (batter) and 1:50 (base). The overall conveyance is lined by *axonophus compressus* (cow grass) with a mild gradient of 0.2%. The grassed swale is designed by taken into consideration of peak flow attenuation, soil erosion and safety to the public.

Grassed swale has the ability to reduce on-site peak flow rates by increasing the roughness of the channel and infiltration rates. These vegetated systems also provide runoff quality treatment by removing low concentrations and quantities of TSS, heavy metals, hydrocarbons and nutrients from stormwater. The vegetated systems remove pollutants by means of sedimentation, filtration, soil absorption and plant uptake.
### 3.5 Runoff Quantity Control

On-site detention (OSD) facility was selected as stormwater quantity control facilities for this project. On-site detention pond which contains of drypond and subsurface storage tank and module was designed to regulate the outflow discharge to pre-development discharge limit.

The OSD sizing method for estimating Permissible Site Discharge (PSD) and Site Storage Requirement (SSR) is the Swinburne Method, developed at the Swinburne University of Technology in Melbourne, Australia. 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 SSR is the total amount of storage required to ensure that the required PSD is not exceeded and the OSD facility does not overflow during the storage design storm ARI.

For above-ground storage, the equation is used to calculate the PSD and SSR for the site area:

\[
PSD = \frac{a - \sqrt{a^2 - 4b}}{2}
\]

\[
a = \left(4 \frac{Q_a}{t_c}ight) \left(0.333 t_c \frac{Q_p}{Q_a} + 0.75 t_c + 0.25 t_{cs}\right)
\]

\[
b = 4 Q_a Q_p
\]

where,

\(t_c\) = peak flow time of concentration from the top of the catchment to a designated outlet or point of concern (minutes)

\(t_{cs}\) = peak flow time of concentration from the top of the catchment to the development site (minutes)

\(Q_a\) = the peak post-development flow from the site for the discharge design storm with a duration equal to \(t_c\) (l/s)

\(Q_p\) = the peak pre-development flow from the site for the discharge design storm with a duration equal to \(t_c\) (l/s)

\[
SSR = 0.06 t_d (Q_d - c - d)
\]

\[
c = 0.875 PSD \left(1 - 0.459 \frac{PSD}{Q_d}\right)
\]

\[
d = 0.214 \frac{PSD^2}{Q_d}
\]

where,

\(t_d\) = selected storm duration (minutes)

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

The critical storm duration that produces the largest required storage volume is different from the time of concentration used for peak flow estimation. The maximum storage volume must be determined for a range of storm duration as given in Figure 4.
Figure 2 Relationship Between $t_c$ and $t_{cs}$ for the Swinburne Method (DID, 2000).

Figure 3 Swinburne Method Assumptions $t_f$ = time for storage to fill (DID, 2000).

Figure 4 Typical Relationship of Storage Volume to Storm Duration (DID, 2000).
4. PROPOSED DRAINAGE SYSTEM

The proposed drainage system which is known as Bio-ecological Drainage System (BIOECODS) for this project is consistent with objectives of new stormwater management approach which focus on the control of both the quantity and quality of urban runoff. This has been embodied in the concept of ecologically sustainable development which is aimed at ensuring that development can occur without long-term degradation of natural resources and the environment.

4.1 Grassed Swale

There are two types of grassed swale, i.e. perimeter swale and ecological swale (Figure 5). Perimeter swale is designed to cater any excess water from individual building whilst the flow from impermeable surface will directed to the grass swale. The perimeter swale is defined as grass earth channel combined with subsurface single module (Figure 6) which enclosed within a permeable geotextile.

The flow from perimeter swale will be conveyed to ecological swale as main conveyor. The ecological swale is a grass earth channel combined with two numbers of single subsurface module which enclosed within a permeable geotextile.

Figure 5 Typical Cross Section for Grassed Swale.
4.2 Detention Storage

The excess stormwater is stored in the subsurface detention storage as illustrated in Figure 7. The storage modules have been designed to be placed at the connecting points, junction and critical point of the system. The storage module is categorized into Type A and Type B with different storage capacity and can be arranged accordingly to suit site conditions. These detention storage are provided to reduce flows from the building, regulating flow velocity which cause the gravity settling of particulates and increase the infiltration process where all these mechanisms will control the quality and quantity of stormwater runoff.

4.3 Dry Pond

The excess stormwater is also stored in the dry pond constructed with a storage function. The dry pond (Figures 8 and 9) is a detention basin with the purpose to temporary store the stormwater runoff. This detention basin is design to store to the surface of 600mm of the excess rainfall under design average recurrent interval of 10-year and blend with the surrounding landscape. The outflow path is controlled by orifices in order to drain the dry pond system in less than 24 hours. Therefore, the quantity and quality of the runoff from developed areas can be maintained to be the same as pre-development condition.

Dry pond is normally dry or empty when not in operation. It is utilised for multi-purpose use to incorporate recreational areas.
Figure 7 Typical Cross Section for Detention Storage.

Figure 8 Side View of Dry Pond.
5. IMPACTS OF URBANISATION

The land use changes from undeveloped to developed areas have caused approximately 50% increment of peak flow discharge from 0.36 m$^3$/s to 0.55 m$^3$/s on receiving water body. PSD and SSR are estimated as 0.34 m$^3$/s and 434 m$^3$ respectively. The required storage volume will be stored in dry pond and subsurface storage module.

The primary outlet orifice is sized to discharge the PSD assuming free outlet conditions when the storage is full. Broad-crested weir is sized for the estimated major system ARI flow from the site for 50 year ARI.

6. CONCLUSION

The proposed BIOECODS is an applicable concept as new storm water management approach to minimize the impact of urbanization on the environment. It adopts an integrated approach to obtain both practical and cost effective solutions for drainage system.

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