Green Technology as Alternative Solution for Flood, Water Scarcity and Water Pollution

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Introduction

1. Urbanisation of a catchment will always increase the quantity of strormwater runoff. To maintain the post-development peak flow of runoff equal or less to the pre-development peak flow of runoff as idealised in 'zero peak flow contribution', "control-at-source" concept is the crucial solution to minimise the impact development on stormwater quantity.
2. This paper presents an alternative green technology solution for flood, water scarcity and water pollution based on a case study of Peak Flow Attenuation Using Infiltration Engineering Systems and Storage Tank At USM's Perak Branch Campus (DID, 2003). Three types of storage and infiltration tanks were designed and their performances were evaluated through a 15-month data collection. These systems were constructed to increase the flow attenuation. The results of this study can be used as a reference or a guide for designing a subsurface storage or infiltration tank at any designated flow reduction level of a similar system.
3. This study had lead to several urban stormwater management projects in Malaysia. These include the national pilot and show piece project of Bio-ecological Drainage System (BIOECODS) in Engineering Campus, Universiti Sains Malaysia, Hospital Bahagia Ulu Kinta, Ipoh, Health Klinik at Jalan Tupai, Taiping and also the recent development of Kwasa Damansara township at Sungai Buloh, which is the Employee Provident Fund's (EPF) RM 50 billion project.

Background

4. Rapid urban growth in Malaysia over the last 30 years has resulted in increased stormwater flow into receiving waters, increases in flood peaks, and degraded water quality. Traditionally, stormwater management in Malaysia which adopts the rapid disposal practice and conveyance-oriented approach has failed to keep up with the country's rapid pace of urbanization and industrialization. Stormwater systems so designed will collect runoff at some point, and immediately and rapidly convey it to a discharge point, apparently to minimize damage or disruption that could result forms its passage to downstream areas. In the past, stormwater runoff has been generally regarded as a nuisance that must be disposed of as quickly and efficiently as possible.
5. The consequence of removing the stormwater from the land surface so quickly is to increase volumes and peak rates of flow discharge and finally overloading conventional drainage system. This results in a greater runoff that generally requires expensive enhancement of drainage network to reduce severity and frequency of flooding in urban areas. This also results in a higher pollutant washoff from the urban areas leading to deteriorate water quality in the receiving water bodies (Zakaria et al., 2003).

What Needs to Change

Control at Source Approach

6. In response to the needs for paradigm shift the way stormwater is managed, the Malaysian government has launched the Urban Stormwater Management Manual for Malaysia, or

known as MSMA (DID, 2000) incorporating the latest development in stormwater management that is known as control-at-source approach. From year 2001 onwards, all new development in Malaysia must comply with new guideline that requires the application of treatment devices or facilities to control stormwater from the aspect of quantity and quality runoff to achieve zero development impact contribution. This concept of treatments will be able to preserve the natural river flow carrying capacity.

7. Besides that, DID also decided that it is timely for the first edition be improved after ten (10) years time lapse. MSMA 2nd Edition and also Malaysian Standard on Urban Stormwater Management (MS 2526) are developed through contributions of professionals from the Government as well as private sectors and foreign experts. The Manual has been updated to serve as a source of information and to provide guidance and reference pertaining to the latest best practices for engineers and personnels. This is one of the many initiatives undertaken by DID to further improve its delivery system meeting ongoing Government transformation effort (DID, 2012).

8. The new manual draws on various approach of stormwater facilities now being widely applied worldwide to control the quantity and quality of runoff through detention/retention storage, infiltration facilities which are capable attenuate flow. The goal of the manual is to provide guidance to all regulators, planners and designers who are involved in stormwater management. It identifies a new direction for stormwater management in urban areas in Malaysia.

9. Stormwater quantity control facilities (detention storage facilities), can reduce the peak and volume of runoff from a given catchment, which can reduce the frequency and extent of downstream flooding. Detention and retention facilities have been used to reduce the costs of large stormwater drainage systems by reducing the size required for such systems in downstream areas. The level of runoff quantity control requirements for any size of development or re-development project is "Post development peak flow of any ARI at the project outlet must be less than or equal to the pre-development peak flow of the corresponding ARI ($Q_{post} \leq Q_{pre}$)".

10. Detention storage facilities are the core elements of achieving one of the major stormwater quantity control criteria which is the post-development peak discharge cannot be more than the pre-development peak discharge. Its achievable with proper locating and sizing of the storage facilities.

What are the options?

Above Ground Storage - Rain Water Harvesting Tank

11. Rainwater harvesting is a technique of collecting rainfall as a supplementary source of water supply for households, commercial and industrial premises, landscape watering, livestock water, and irrigation of agriculture. Rainwater harvesting can be promoted as a sustainable water supply that also significantly improves the lifestyles of people in the community. There has been a paradigm shift in people's behavior more towards the 'green' approach to everyday commodities

12. The rainwater harvesting storage volume cannot be relied upon for detention purposes as this portion may be full or partly full at the onset of rain and therefore ineffective for detention purpose. Therefore, to extent the rain water harvesting tank to reduce runoff and peak flows, it is depends on use of the captured rainwater between storms (drawdown between storms), so that capacity exists to capture a portion of the next storm.

13. Hence, the storage volume that is required for detention storage in the development must therefore be in addition to the storage volume provided for rainwater harvesting.

14. Space limitations are rarely a concern with rainwater harvesting if considered during building design and site layout. Storage tanks can be placed underground, indoors, on roofs, or adjacent to buildings depending on intended uses of the rainwater.

Above Ground Storage - Detention Pond

15. Detention pond is a storage facilities constructed in public open space areas outside of private properties, or in conjunction with public recreation and sporting facilities. In general, storage facilities such as detention ponds are used for controlling stormwater quantity impacts resulting from larger urbanising catchment.

16. Detention pond is primarily designed for attenuating runoff from developed areas through regulated outlet structures. An overflow spillway set near the top of the embankment is required to safely discharge larger storms that exceed the basin capacity. The facility is typically designed to limit discharge to the pre-development stage, while storing water temporarily. On top of that, detention pond also serves water quality treatment and ecological function. With aquatic and wetland plants planted along the water fringes, it provides some water quality treatment. Extended exposure to sunlight in a pond will also help to breakdown certain pollutants.

17. The design storm for estimating the required storage volume shall be based on the major storm runoff quantity system, i.e. up to 100-year average recurrence interval (ARI). However, in designing a detention storage facility to meet the flow control objectives, it is necessary to consider the behaviour of the pond storage by examining:

    - the degree of reduction of flows from the catchment;
    - the depths and duration of ponding; and
    - the frequency at which the overflow spillway comes into operation.

Below Ground Storage - Subsurface Storage Tank

18. The below ground storage may be used as temporarily storage for on-site detention (OSD) design only. Underground detention storage facilities are primary used in newly developed area where land cost and/or availability are major concern. Below ground storages however, are out of sight, occupy minimum land space. Underground detention storage facilities are designed to be dry most of the time. When preparing a design for below ground storage, designers should be aware of any statutory requirements for working in confined spaces. Access should be provided to allow routine inspection and maintenance.

19. The below ground storage are built under parking lots, sport field, park lawn or other paved surfaces in commercial, industrial and residential areas. Underground detention storage facilities can be constructed from concrete, steel and aluminium, plastic (HDPE) material, such as:

    - modular, precast concrete units, adapted from circular concrete pipe and rectangular culvert sections;
    - circular, galvanised steel tank;
    - modular cell providing a large void space within a matrix of polypropylene or other plastic materials.

20. The advantages of the underground detention storage facilities are as follow:

    - the system are ideal for highly urbanised area, particularly in area where land is expensive or may not be available for pond;
    - the system can be installed quickly;
    - the system are very durable. Once in the ground, most systems can last for more than 50 years;
    - Because theses system underground, local residents are less likely to have access to them, hence making them safer than ponds or other above ground stormwater facilities.

21. The disadvantages of the underground detention storage facilities are as follow:

    - the underground system are not designed to provide storm water quality benefits, unless if they are included in a treatment train type stormwater management system;

- These systems may require more excavation than surface ponds or other above ground stormwater facilities;
- Recharge of the groundwater from an underground detention unit without pre-treatment may contribute to groundwater contamination. Therefore, it is not recommend that underground system be designed for sites with high groundwater tables;
- These systems are more difficult to maintain and clean than above ground systems.

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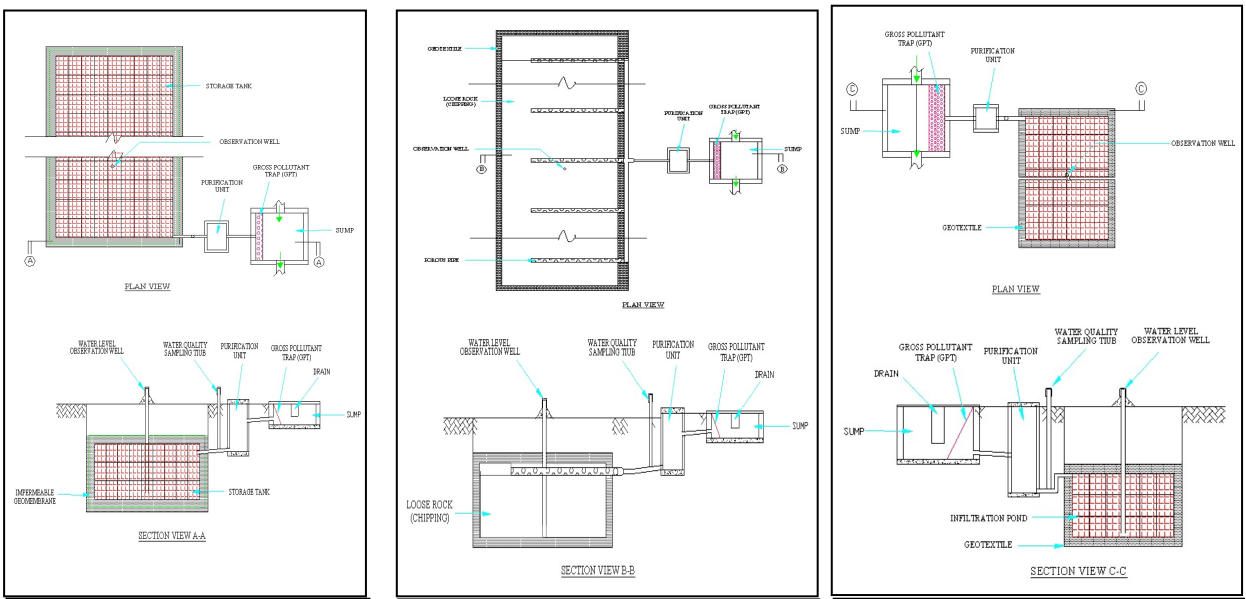
Appendix

Project Background

1. The project was located in previous USM Engineering Campus in Tronoh, Perak Darul Ridzuan. The objective of the project is to study the peak flow attenuation of stormwater for existing buildings (DID, 2003). There were three types of subsurface on-site detention/retention systems being constructed namely Modular Storage Tank at Hydrology Laboratory, Loose Rock Infiltration Tank at Jaya Hostel and Modular Infiltration Tank at Multi-purpose Hall (Figure 1). Even though the design of these subsurface tank systems were carried out in early 1999 before the new urban stormwater management manual has been introduced, the main objective of this project is in line with the direction the stormwater management manual.



Modular Storage Tank at Hydrology Laboratory	Loose Rock Infiltration Tank at Jaya Hostel	Modular Infiltration Tank at Multi-purpose Hall

Figure 1 Subsurface on-site detention/retention systems

2. The systems were designed as detention (Modular Storage Tank) or retention (Loose Rock Infiltration Tank and Modular Infiltration Tank) storage facilities. The flow was diverted from channel into storage tanks by uPVC pipe which was connected between sump and subsurface storage tanks. The outflow from the channel was regulated by control structure which consists of sump and uPVC pipe. There were two cases of control structures being studied during this project as tabulated in Table 1.

Table 1 Details of Inlet Pipe for Two Cases.

Parameter	Location		
	Hydrology Laboratory	Jaya Hostel	Multi-purpose Hall
Case 1 (original design)			
Size	3”	3”	3”
Slope	5%	5%	5%
Capacity (m^3/s)	0.0085	0.0085	0.0085
Case 2 (modified design)			
Size	2 nos 6”	6”	2 nos 6”
Slope	5%	5%	5%
Capacity (m^3/s)	0.104	0.052	0.104

3. The construction of these systems took approxiametely half a month for each system from end of 1999 to early of 2000. The construction procedure includes excavation for storage tank, sand bedding, installation of modular tank or loose rock tank, sand filling, backfilling and turfing. The anxillary works of the system are pipe connections, installation of purification unit and control structure.

4. The data of rainfall and water flow at inlet and outlet channels were retrieved from automatic data collection system. Data collection was carried out for a 15-month duration which covers dry and wet seasons in West Peninsular Malaysia.

Result and Analysis

5. The results of this study are summarised in Figure 2 for three different study sites in this project. Two cases of control structures known as Case 1 and Case 2 were considered as elaborated above with the latter case had increased flow capacity into storage tank. The performance of the system is measured by the percentage of flow reduction as given in y-axis while x-axis denotes the channel flow at inlet channel. The difference of inlet and outlet channel flow is considered as flow reduction.

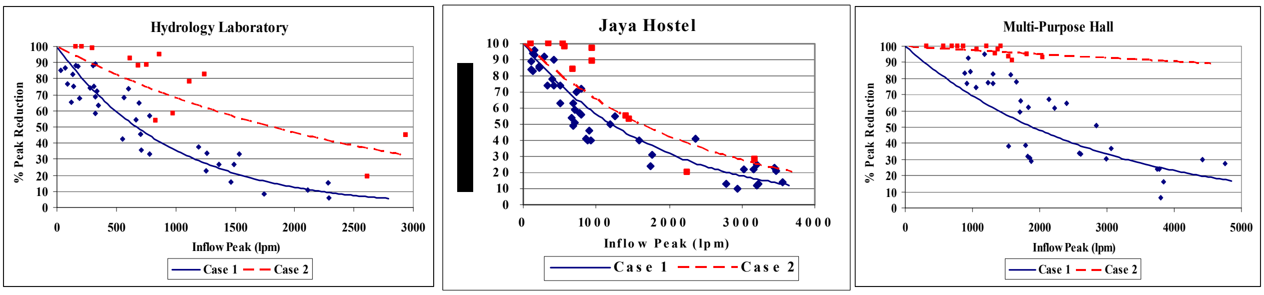


Figure 2: The performance of the system

6. The performance of the system is clearly related to the characteristic of the control structure. From the results, Multi-purpose Hall has the highest percentage of peak flow reduction followed by Jaya Hostel and Hydrology Laboratory. The system at Multi-purpose Hall has 0.97m^3 detention volume compared to Jaya Hostel and Hydrology Laboratory with 0.47 m^3 and 0.20 m^3 respectively before the runoff starts flowing out from the sump providing that the subsurface storage is not full and the distance between uPVC pipe invert and sump invert are the same for all these systems.

7. In term of comparison for Case 1 and Case 2, it is obviously found that the performance of Case 2 is better than Case 1. Case 2 with higher capacity of uPVC pipe due to either

increase the pipe nominal diameter size or pipe quantity gives improvement of peak flow attenuation by 28.6%, 14.5%, 58.3% at peak inflow of 2500 liter per minute (lpm) for Hydrology Laboratory, Jaya Hostel and Multi-purpose Hall respectively.

8. The time to empty the storage tank is governed by the characteristic of the surrounding soil. Soil classification and infiltration tests were carried out in these sites to determine the soil characteristics. The results show that the soil adjacent to Multi-purpose Hall and Jaya Hostel are classified as silty sand to coarse sand with high permeability with infiltration coefficient of 0.084m/hr and 0.018m/hr respectively.
9. Generally, loose rock infiltration tank requires longer empty time and larger storage tank compared to modular infiltration tank to cater for the same event even though it has smaller peak flow in this study.
10. Comparison of inflow volume and storage volume at a particular time was made. Inflow volume is calculated from the difference of inlet and outlet flow at every interval of 1 minute while storage volume is calculated from recorded water level in the storage tank. The difference between inflow and storage volume is resulted by the outflow through infiltration process. Modular infiltration tank at Multi-purpose Hall records significant reduction for these volume differences due to its higher infiltration rate at surrounding soil and larger effective area for infiltration occurred compared to loose rock infiltration tank at Jaya Hostel. This also indicates that the actual required storage volume can be reduced if the characteristic of the surrounding soil is known.