COMPARISON BETWEEN PIPE SYSTEM AND BIOECODS SYSTEM BY USING STORM WATER MANAGEMENT MODEL (SWMM)

by

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ABSTRAK

Pembangunan secara mendadak telah banyak mendatangkan masalah dalam pengurusan air larian ribut seperti banjir kilat di kawasan Bandar. Sistem perparitan konventional di mana akan mengalirkan air larian dengan secepat mungkin ke dalam sungai (pembuangan cepat). Sistem konventional ini berdasarkan manual Planning and Design Procedure by Department of Irrigation and Drainage (DID) pada 1975. Akan tetapi, sistem tradisional ini telah menyebabkan berlakunya banjir di hilir sungai. Dengan itu, manual baru telah diperkenalkan oleh DID pada 2001. Manual baru ini dikenali sebagai "Storm Water Management Manual (MSMA)". Aplikasi Amalan Pengurusan Terbaik dan Kawalan di punca telah digunakan dalam sistem baru ini.

Sistem baru ini telah diimplementasi oleh Universiti Sains Malaysia dengan kerjasama DID. Lokasi kajian tersebut terletak di Kampus Kejuruteraan, USM, Seberang Perai Selatan, Pulau Pinang, Malaysia. Untuk mengesan keberkesanan sistem baru, simulasi sistem paip (pembuangan secepat mungkin) dan sistem BIOECODS (Kawalan di punca) telah dijalankan dalam tesis ini.

ABSTRACT

Urbanization has led to problems in urban storm water management such as flash flood. A conventional drainage system has been designed to mitigate flash flood by transporting storm water runoff out of the catchments into river as fast as possible (rapid disposal). This conventional drainage system is based on manual "Planning and Design Procedure by Department of Irrigation and Drainage (DID)" in 1975. However this conventional system has led to the occurrence of flash flood at the downstream of the catchments. Therefore, a new manual has been introduced by DID Malaysia. This new manual is known as "Storm Water Management Manual (MSMA)" in 2001. "Best Management Practices (BMPs)" or control at source concept has been applied in this new manual to achieve zero development impact contribution.

This new drainage has been implemented by Universiti Sains Malaysia in collaboration with DID. The site of study is located in USM Engineering Campus Seberang Perai Selatan District, Pulau Pinang, Malaysia. In order to verify the effectiveness of this new drainage system, simulation of pipe system (rapid disposal) and BIOECODS system (control at source) has been carried out as a comparison.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Large portions of agricultural and ex-mining land are being converted to impervious areas to improve the needs due to rapid urban growth. This has resulted in the change of hydrological cycle where the recharges of infiltration and ground water have been decreased, river runoff changes imposing high peak flows and large runoff volumes from urban areas.

In 1971, a serious damage over Malaysia due to flood had indicated the importance of effective urban drainage. The traditional drainage concepts such as rapid disposal, localized, reactive and mono-functional drainage have been widely practiced in Malaysia and this practice is based on the 1975 Department of Irrigation and Drainage Malaysia (DID), Urban Drainage Design Manual. However, this approach has led to the increase in the occurrence of flash flood as the result of the increasing in surface runoff, peak discharges and shorter flow duration. (The University of Mississipp, 2004)

To curb this problem, DID has introduced New Urban Drainage Manual known as Storm water Management Manual for Malaysia (Manual Saliran Mesra Alam or MSMA) which is effective from 1st January 2001. This new guidelines is an application of Best Management Practices (BMP's) to control urban storm water from the aspects of quantity and quality of runoff. A more environmentally concept known as control at source has been introduced in this new manual. This concept utilizes detention/retention, infiltration and purification process. The quantity and quality of the runoff will be maintained to be the same as pre-development condition which is known as uncontaminated zero contribution to the peak discharge.

1.2 Research Objectives

Under this research, there will be a multiple objectives. The main objective of this research is to compare between rapid disposal drainage system (pipe system) and control at source drainage system (BIOECODS system) in USM Engineering Campus by using Storm Water Management Modelling (XP-SWMM). Furthermore, the effectiveness of BIOECODS system will be studied. In addition, the capability and effectiveness of XP-SWMM will be explored.

1.3 Research Methodology

This research involves in model simulation. A model is a representation of a system in some form other than the system itself. Simulation is a process of conducting experiments with a model for the purpose of understanding the system.

Under this research, XP-SWMM is used to model the hydrologic catchments processes and simulate the hydraulics of pipe system and BIOECODS system. The link node model of XP-SWMM is used to represent the characteristic of the catchment and drainage system. A link represents a hydraulic element of flow in the system. A node represents the junction of hydraulic elements. Besides, a node can also represent a storage device such as pond or lake, or a point junction to represent a point of change in channel or conduit geometry.

The procedure of modeling simulation between both systems is almost similar. The only different is the parameter of the design and conveyance shape or geometry. For example, the manning coefficients are different between pipe system and BIOECODS system. (Table 1.0)

Table 1.0 Manning Coefficients for Pipe System and BIOECODS System

(Department Of Irrigation and Drainage Malaysia)

System	Parameter	Manning (n)
Pipe	Spun Precast Concrete	0.013
	Fibre Reinforced Cement	0.013
BIOECODS	Surface Swale	0.035
	Sub-surface Swale	0.100

Actually, simulation includes three simple basic procedures, there are design for a real or proposed system, execute the model on computer and analyze the execution output. The simulation procedures of this research are shown Figure 1.0.

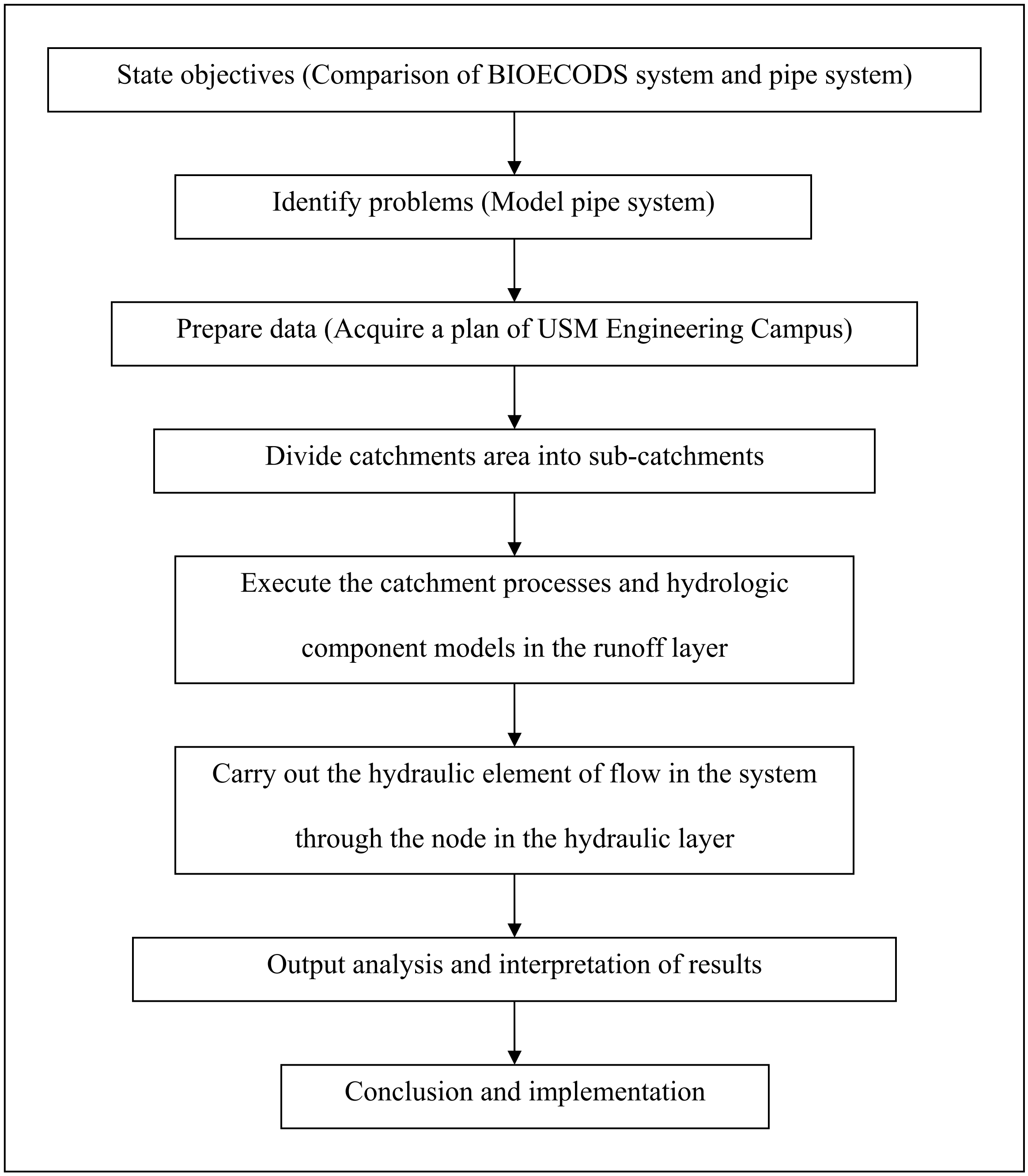

Figure 1.0 Simulation Procedures

1.4 Importance of Research

Through this research, comparison between rapid disposal system and control at source system can be studied. From this study, the effectiveness of each system can be evaluated. This research can also form as a guideline for future engineers in designing both systems.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In nature, when rainwater falls on a natural surface, some water returns to the atmosphere through evaporation, transpiration, infiltration, percolation and some runs off the surface. However, urbanisation has caused in the growth of impervious areas which are certainly have a significant on these processes. The effect of urbanization which increases the surface runoff is shown in Figure 2.0. (Butler, 2000; W.Davies, 2000)

The rapid rate of surface runoff on impervious area in urban area has led to our increase of the peak flow. Therefore, the risk of sudden flooding will be higher.

Besides, in a developed urban area, the rapid runoff of storm water is likely to cause pollutants. This is because much pollutant materials such as oil and dust will be washed during storm runoff and flow into the river as water body. Similarly, replacing the natural drainage by urban drainage such as combined system which will pollutants from the wastewater to enter the river. The effect of urbanisation on peak rate of runoff is shown in Figure 2.1.

The pollution of river will also affect the ecology of the aquatic life by destroying the natural self purification processes such as deoxygenating As a result; the habitat of the marine life will also be ruined.

Overall, urbanization presents a set of modern environmental challenges the ability to solve the problems effectively at a minimum of cost. However, the challenges cannot be considered to be responsibility of single party or profession alone. Respective authorities must also get involved in these challenges including policy-makers, engineers, and environment specialists, together with the citizens.

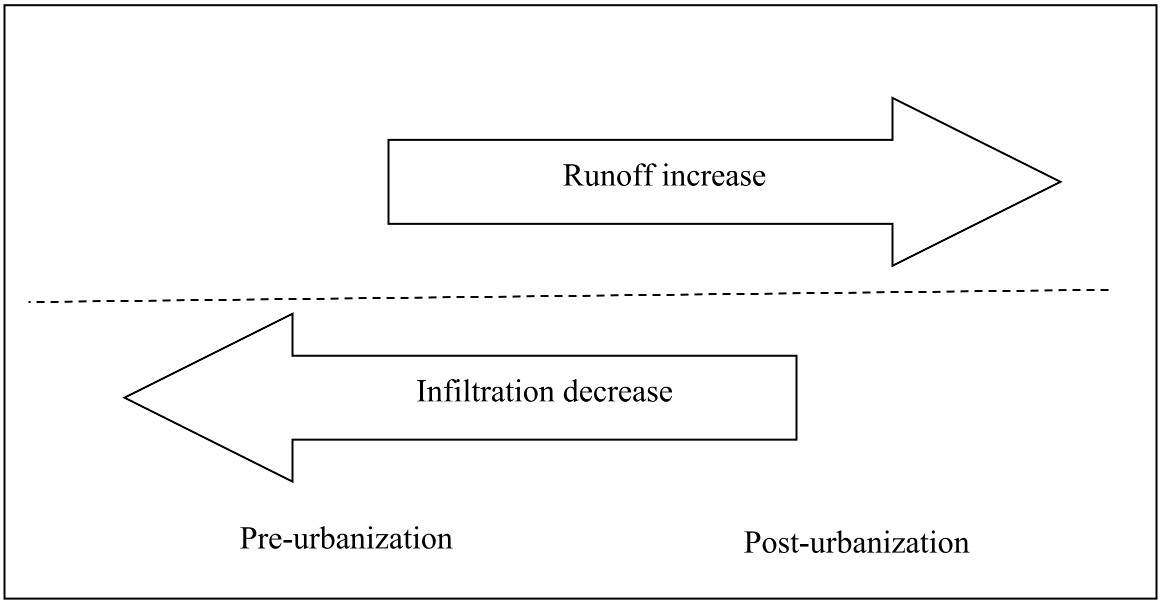

Figure 2.0 Effects of Urbanization on Runoff

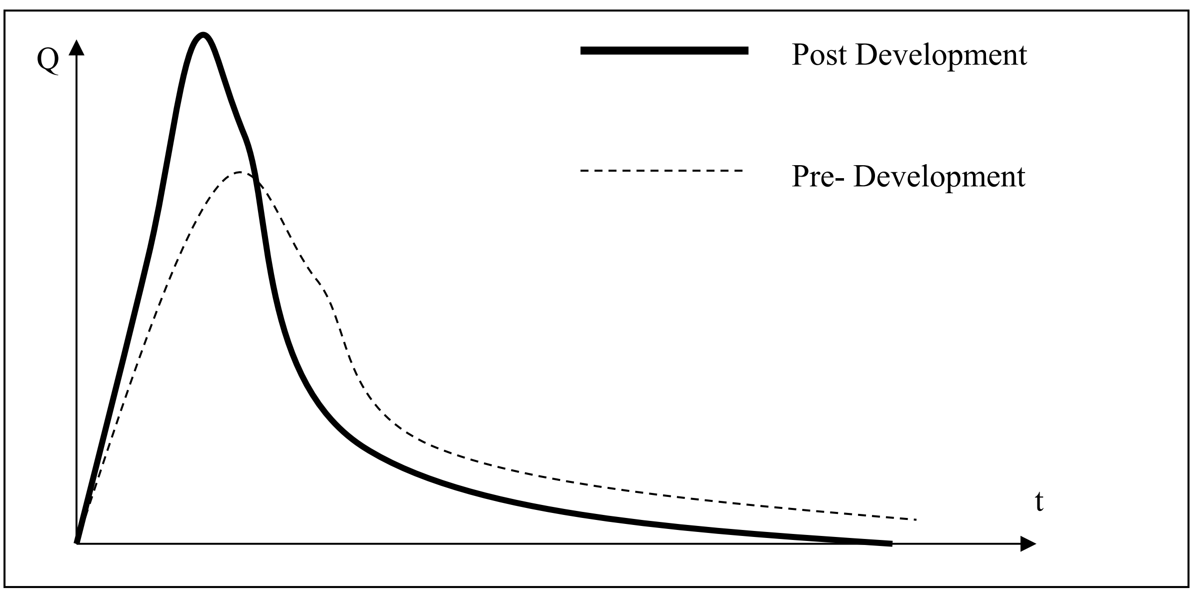

Figure 2.1 Effect of Urbanization on Peak Rate of Runoff

2.2 Concept of rapid disposal

The conventional way to manage the storm water is by using the concept of rapid disposal for the drainage system. However, such concept has caused a lot of problems in managing storm water. The following are some of the problems that contributed by the system base on the concept of rapid disposal:

- Flooding
- Water pollution
- Bad effect of ecology system
- Failure of river bank in urban area
- Rubbish problems
- Settlement

(Zakaria, 2003)

2.3 Types of systems

There are basically two types of conventional sewerage system (to control storm water as well as wastewater) which use the concept of rapid disposal:

- Combined system (is not used in Malaysia, only as comparison)
- Separate system (is currently used in Malaysia nowadays)

Combined system allows wastewater and storm water flow together in the same pipe. Meanwhile for separate system, wastewater and storm water are kept in separate pipe. However, some towns use hybrid systems, for instance a ‘partially-separate system and majority of storm water is conveyed by a separate pipe.

2.3.1 Combined system

Figure 2.2 is the typical layout of combined sewer system (schematic plan):

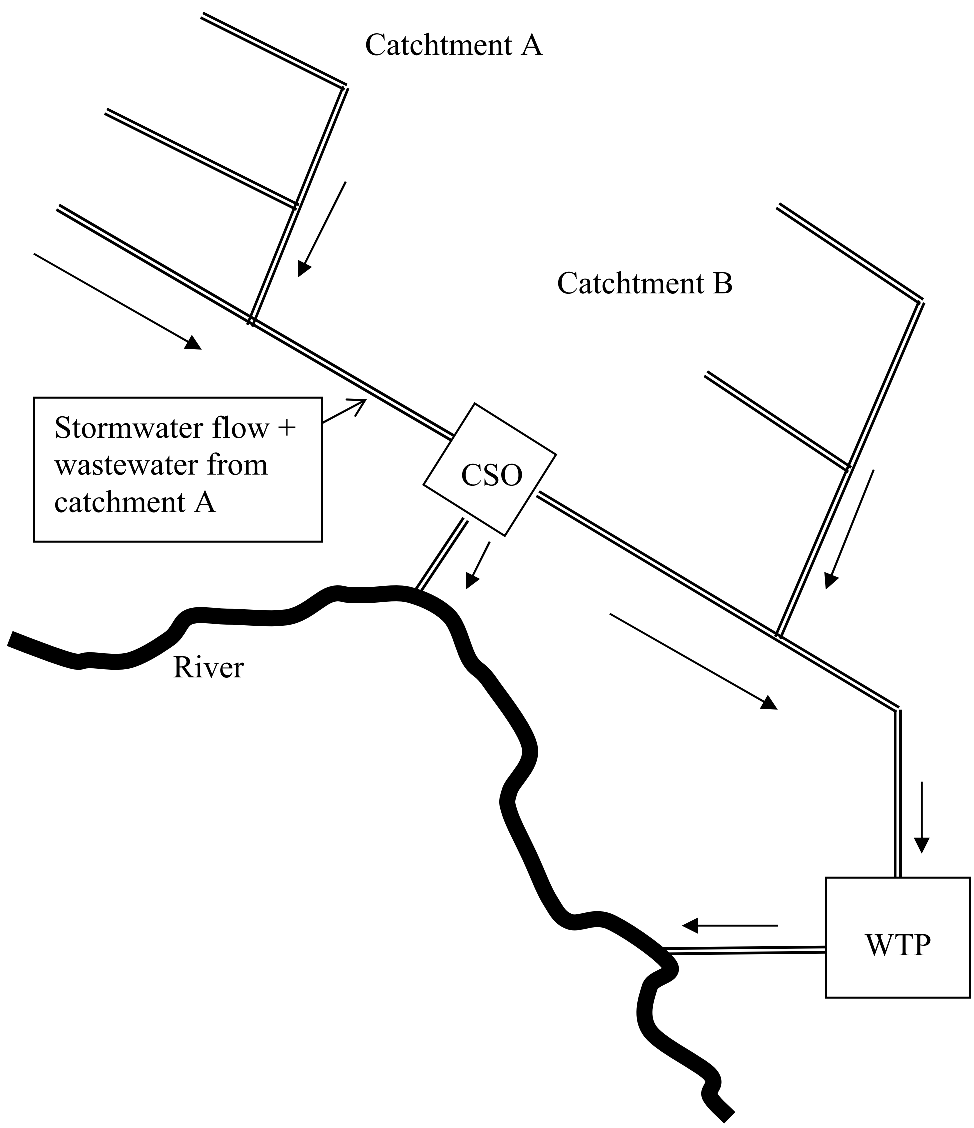

Figure 2.2 Typical Layout of Combined Sewer System

In Figure 2.2, the combined sewer system carry storm water and wastewater together in the same pipe, and the ultimate destination is the wastewater treatment plant (WTP) which is normally located at a short distance out of town. In dry weather, the system only carries wastewater flow. However during rainfall event, the flow in sewer system will be increased due to the addition of storm water.

It is not economically to provide capacity for this flow along the full length of the sewer. Also, at the WTP, it would also be unfeasible to provide this capacity in the treatment plant. Therefore, the solution is to supply structures in the sewer system which is known as combined sewer overflows (CSO).

The main function of the CSO is to carry an inflow and divide into two outflows. One is going to the WTP (the continuation flow, or flow retained) and another is going to the watercourse (the spill flow) which is shown in Figure 2.3. If the combined flow does not exceed the setting of CSO, all flows will proceed to the WTP only. If the flow rate increases, so does the combined flow exceed the setting of CSO. Then, there will be overflow (spill flow) to the stream and the flow retained (continuation flow) in the system will be conveyed to WTP. (Butler, 2000; W.Davies, 2000)

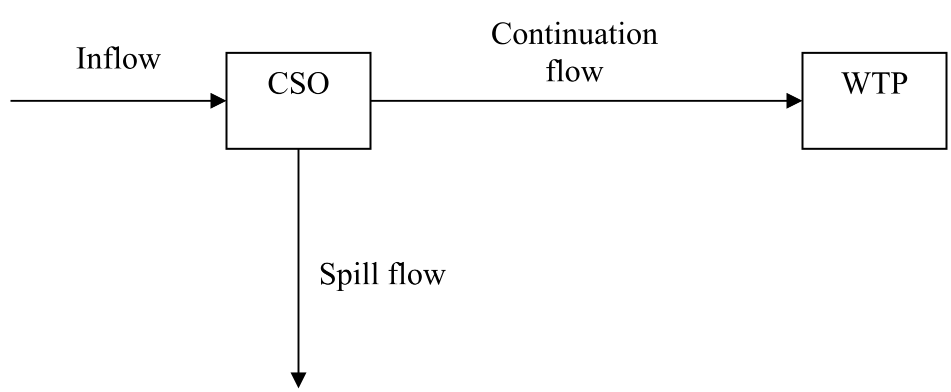

Figure 2.3 CSO of Inflow and Outflow

The problems of combined system

If the setting of CSO is too low, then the spill flow takes place prematurely and the capability of the continuation pipe will be under-used. In other word, an unnecessarily large volume of polluted water will flow into the watercourse. Whereas, the setting of CSO is too high, then it might cause to the excessive surcharge of the upstream part. Moreover, too much flow might be forced down the continuation pipe leading to flooding elsewhere in the sewer system. (Butler, 2000; W.Davies, 2000)

It can be simplified that CSO causes pollution and this is an important drawback of combined system.

2.3.2 Separate system

Figure 2.4 shows a typical layout of separate sewer system (schematic plan)

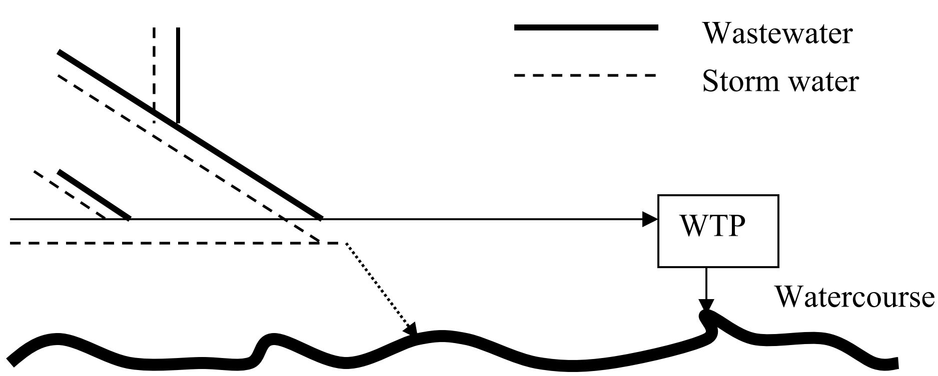

Figure 2.4 Typical Layout of Separate System

Obviously, in separate sewer system, storm water and wastewater are carried in separate pipe as shown in Figure 2.4. Usually, both pipes are laid side by side. In addition, the size of storm water pipe is normally larger than the wastewater pipe. The storm water pipe is designed to be about the same size as the equivalent combined sewer. Meanwhile, the wastewater pipe is designed to carry the maximum flow all the way to the WTP.

Wastewater pipe carries wastewater along the system until to WTP for treatment. The treated water then will be disposed to watercourse. In the meantime, storm water pipe only carries storm water for short distance, and then it will straight go to watercourse without treatment.

The problems of separate system

To achieve the perfect separation in separate sewer system is impossible due to the difficulty to ensure that the polluted flow is only carried in wastewater pipe. Besides, storm water will also be polluted by washing-off of pollutants from the catchments surface and so on. Therefore, the watercourse will be polluted.

Also, rainwater can enter the wastewater pipe by two ways; there are infiltration and direct inflow. As a result, the flow in the wastewater pipe will increase and this excess flow is not taken account into in the design. Hence, it will cause the wastewater pipe to be under-designed.

2.3.3 Comparison of combined system and separate system

The advantages and disadvantages of both systems are listed in Table 2.0.

Table 2.0 Comparison of Combined System and Separate System

Separate system	Combined system
Advantages	Disadvantages
The potential to pollute watercourse is less because do not have CSO.	May cause pollution of watercourses because CSO need to keep main sewers and treatment works to feasible size.
Smaller wastewater treatment works.	Larger treatment works inlets necessary, probable with provision for storm water diversion and storage.
Storm water pumped only if necessary.	Higher pumping costs if pumping of flow to treatment is needed.
Wastewater and storm sewers may follow own optimum line and depth. For example, storm water to nearby outfall.	Line is a compromise, and may necessitate long branch connections. Optimum depth for storm water collection may not suit wastewater.
Wastewater sewer small and greater velocities will less cause deposition and decomposition of solids.	Slow, shallow flow in large sewers in dry weather flow may cause deposition and decomposition of solids.
Any flooding will be storm water only.	Foul conditions may be caused if flooding occurs.

Separate system	Combined system
Disadvantages	Advantages
Extra cost of two pipes.	Low pipe construction costs
Additional space occupied in narrow streets in built-up areas.	Economical in space.
More house drains, with risk of wrong connections.	House drainage simpler and cheaper.
No flushing of deposited wastewater solids by stormwater.	Deposited wastewater solids flushed out in times of storm.
No treatment of stormwater.	Some treatment of storm water.

2.4 Best Management Practices (Control at Source)

As discussed previously, the rapid disposal system has lead to the downstream flooding due to the increased volumes and peak flows.

Consequently, a new concept has been introduced in urban storm water management which is also known as "Best Management Practices" (BMPs). Source control ideas are applied in BMPs. The function of this new approach is to provide for the temporary storage of storm water runoff at or near its point of origin with subsequent slow release to the downstream storm water (detention), or infiltration into surrounding soil (retention).

Source control ideas provide a lot of benefits with the respect to runoff quantity and quality control:

- Limitation of peak runoff rate increases due to urbanisation.
- Improvement of downstream drainage capacity problems such as flooding, CSO operation.
- Recharge of soil moisture and groundwater and, hence, watercourse base flow expansion.
- Provision of stored water for re-used.
- Decrease in downstream channel erosion through flow reduction and velocity control.
- Pollutant load to receiving water is reduced.
- Preservation of natural vegetation and wildlife habitat in urban area.

There are three types of source control as follows:

- Local disposal
- Inlet control
- On-site storage

2.4.1 Local disposal

Local disposal are most advantageous for small storms and for water quality control as they do not function well under large storm when the soil has become saturated.

Local disposal methods utilise the natural infiltration capacity of the soil to dispose of the storm water. Therefore, the factors such as vegetative cover, groundwater condition, type and condition of soil which will affect the ability of soil must be known.

There are various variants for local disposal facility available; the most common will be discussed later which are infiltration devices, vegetated surfaces and porous pavements.

Infiltration devices

There are various infiltration devices for local disposal such as soakways, infiltration trenches or basins. A soakways is an underground structure which is stone filled, dry wall lined or built with precast concrete ring units (see figure 2.5). Meanwhile infiltration trenches or basins are constructed by placing coarse sand or gravel. Filter fabric can be used to line the trench or basin to prevent pollutants from entering the groundwater. Infiltration trench is shown in Figure 2.6.

Soakways and trenches can be used in any area that has pervious sub-soils such as gravel, sand, chalk and fissured rock. If the trenches installed on land gradient greater than about 4%, then, “flow checks” at regular intervals should be done. These systems will only function well when the water table is low enough to allow a free flow of storm water into sub-soil at all time of the year. As a result, the base of both systems should be at least 1m above the groundwater level. (Butler, 2000; W.Davies, 2000)

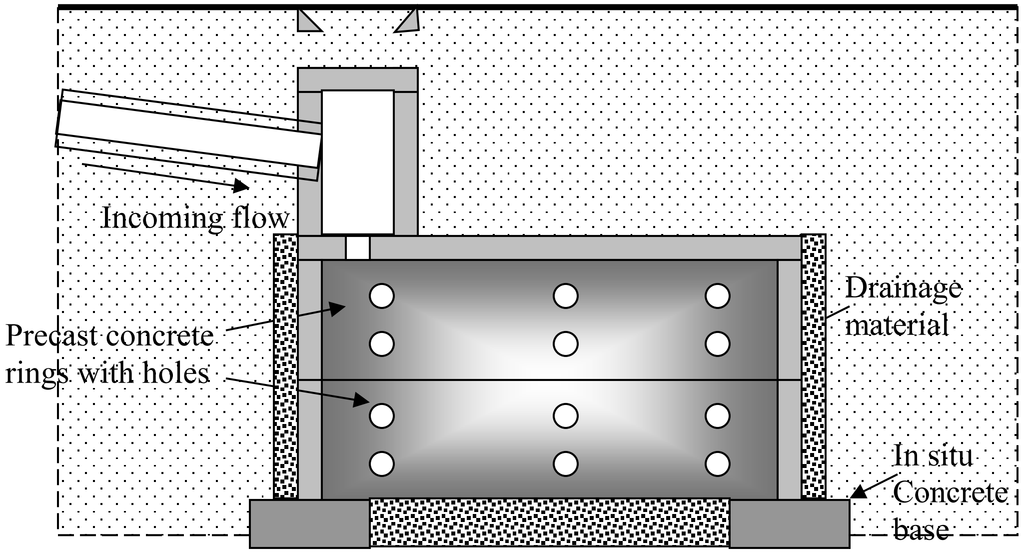

Figure 2.5 Soak Way

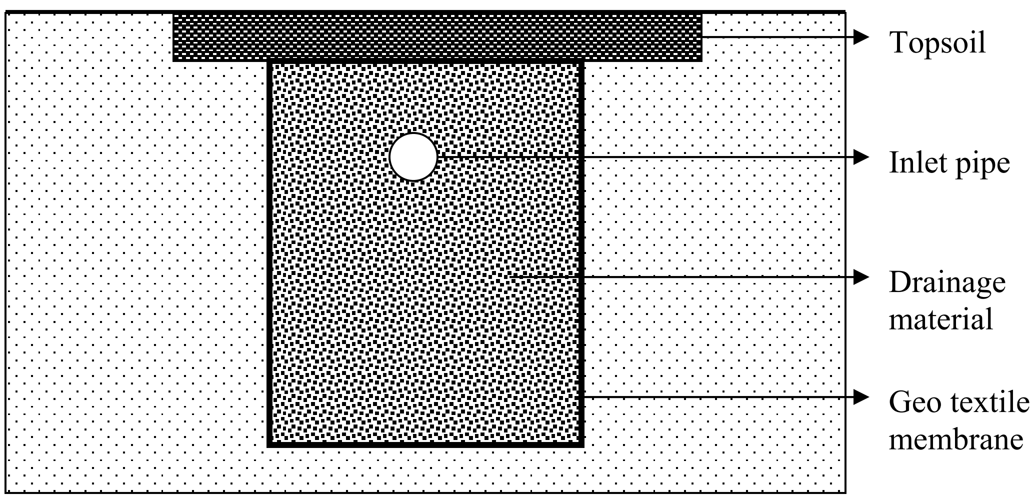

Figure 2.6 Infiltration Trench

Vegetated surfaces

The most common types of vegetated surfaces used in storm water management are filter strips and grassed swales.

Vegetative filter strips is also known as "vegetative buffer strips". The vegetative filter strips are low cost practices that have been found to offer some water quality benefits. A “level spreader” is usually needed as a component of a filter strip for the purpose of spreading storm water runoff evenly onto the strip to avoid “short-circuited” and lose its removal efficiency. Figure 2.7 shows the plan view of a level spreader or vegetative filter strip tested in Charlottesville, Virginia. (Field et al., 1993)

Vegetative filter strips can be used as a “first stage” practice before proceeding to another practice to achieve high performance. For example, runoff from parking lot can be made to pass over a filter strip before entering an infiltration trench. Therefore, high performance will be achieved and infiltration trench will be less likely to be clogged by particles.

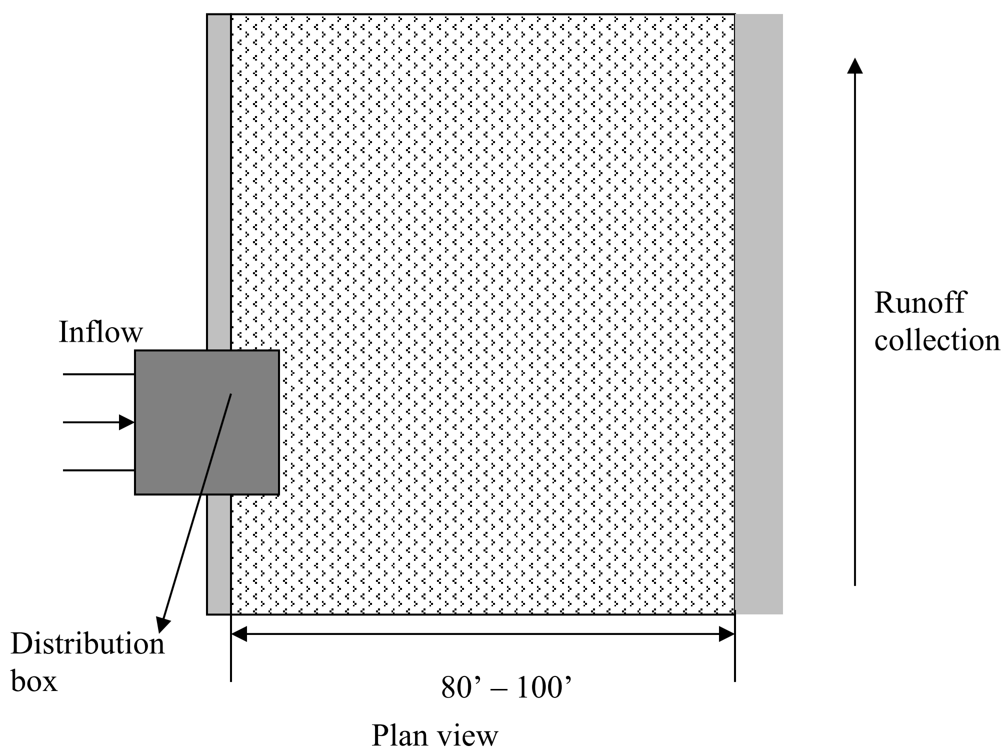

Figure 2.7 Plan Views of a Level Spreader / Vegetative Filter Strip System

Porous pavement

Porous or permeable pavements consist of thin layer constructed from open structured materials such as concrete units filled with gravel, stone or porous asphalt. Two examples are shown in Figure 2.8. Paving is normally placed on top of a high-void aggregate sub-base layer, thus promoting soil infiltration. Long term performance can be achieved by using lateral barriers between blocks to force water to infiltrate near the point of inflow. If the soil below the pavement is not suitable for local infiltration, an impermeable liner is used and the pavement then acts as a storage facilities with flow routed through a perforated under drain system to a conventional drainage system.

Normally, porous pavement is used for car parks, recreational areas or even roads. They do not require day-to-day maintenance but after long periods of use, more than 10 years, then the efficiency levels may be reduced.

At first, these types of surface have infiltration rate greater than 1mm/s. Then, 0.2mm/s infiltration rate still available after 5 years of use although this may deteriorate further.

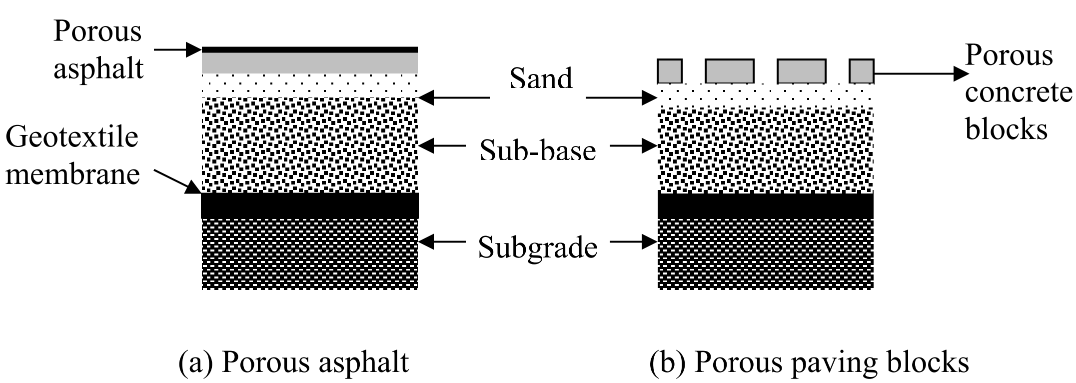

Figure 2.8 Typical Porous Pavement Types

2.4.2 Inlet control

Storm water can also be controlled by detaining it at the point when it runs off the catchments, essentially within the curtilage of the individual property. This can be achieved by restricting the inflow from entering the drainage. These systems include rooftop ponding and pave area ponding.

Rooftop ponding

Storm water can be detained on a flat roof, thus exploiting their storage potential by using flow restrictors on the roof drains. Flat roofs are designed to hold a substantial live load and are sealed against leakage. Therefore, the increase loading in accordance with the recommendation of the Uniform Building Code should be taken into account in the structural design. Figure 2.9 shows a typical design for a flow restrictor that is used.

Maskell and Sherriff (1992) report that the attenuation of runoff using roof storage can reduce peak sewer flows by 30 – 40%. However, the flow restrictors can become blocked, leading either to overtopping or prolonged ponding due to lack of proper inspection and maintenance. A routing municipal inspection and enforcement program is only way to solve this problem. However, commitment for such an inspection program is often not possible to get from the elected officials. As a result, rooftop detention cannot be expected to be effective with time in storm water management. (Butler, 2000; W.Davies, 2000)

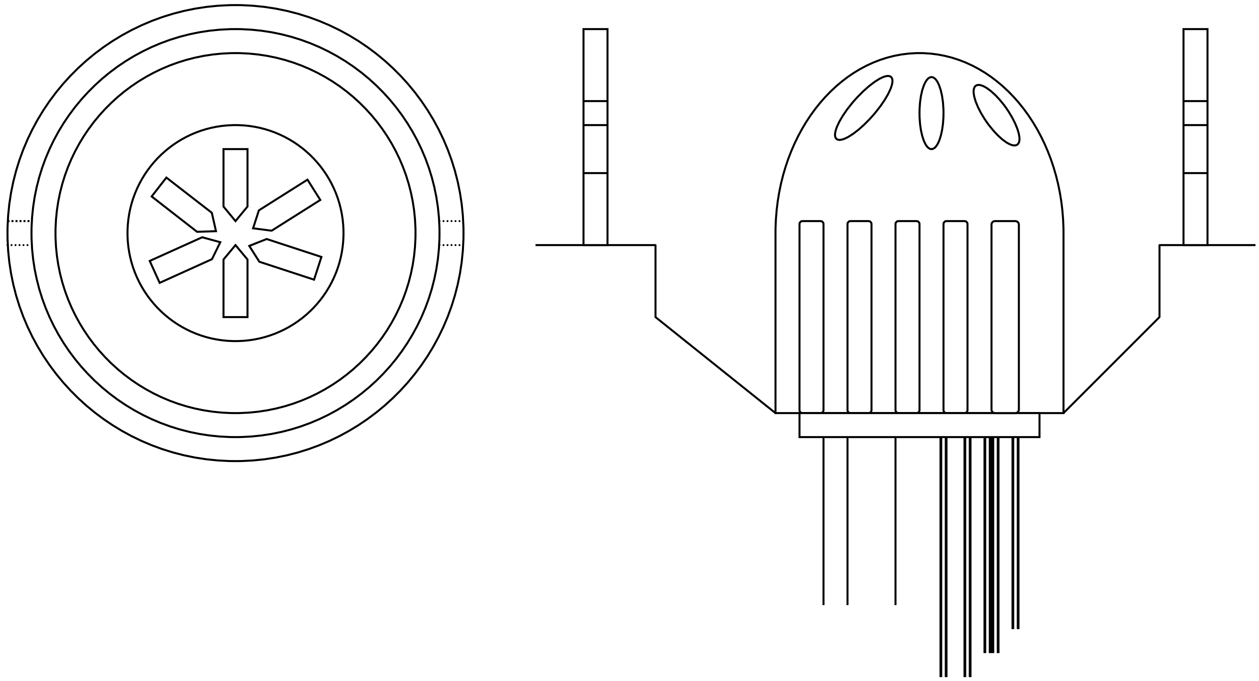

Figure 2.9 Roof Detention Drain Control Ring.

<u>Pave area ponding</u>

Parking lots, paved storage yards, and other paved surfaces can be used for storm water detention. It provides much larger storage surface and greater ponding depth compare to rooftop ponding. However, the use for parking lots for detention needs should be backed up with the staff resources to ensure their continued existence and proper maintenance.

Parked vehicles share the same surface with the parking lot detention. Therefore the detention design should be regarded for the primary use of parking lot to avoid inconvenience and damage to parked vehicles when it rains. So, it is necessary to ensure that the lot does not pond water frequently and it should be inundated for only a short period of time. Thus, it is important for engineer or designer to know the limitations in ponding depths and the frequency of ponding. (Stahre, 1990; Urbonas, 1990)

2.4.3 On-site storage

Storm water is retained locally in buried tanks or surface ponds. The aim is to reduce peak flows from the new development to a level suitable for the existing sewer network. So, the excess flow generated must be stored and released at a controlled rate.

Tanks

There are two types of tanks; on-line detention tank and off-line detention tank.

On-line detention tank are constructed in series with the drainage system and controlled by a flow control at their outlet. Flow passes through the tank until the inflow exceeds the capacity of the outlet. Then, the excess flow will be stored in tank. As the inflow settles at the end of the storm event, the tank begins to drain down, typically by gravity. Figure 2.10 shows an on-line storage tank.

Off-line tanks are built in parallel with the drainage system as shown in Figure 2.10. These types of tank are designed to operate at a pre-determined flow rate, controlled at the tank inlet. An emergency overflow is provided, as for the on-line tank. Flow is returned to the system by gravity or pumping.

Compare to on-line tanks, off-line tanks require less volume than on-line tanks for equivalent performance and hence less space. However, the overflow and throttling devices necessary to divert, regulate and return flows are complicated. So, the maintaining self-cleansing is also difficult.

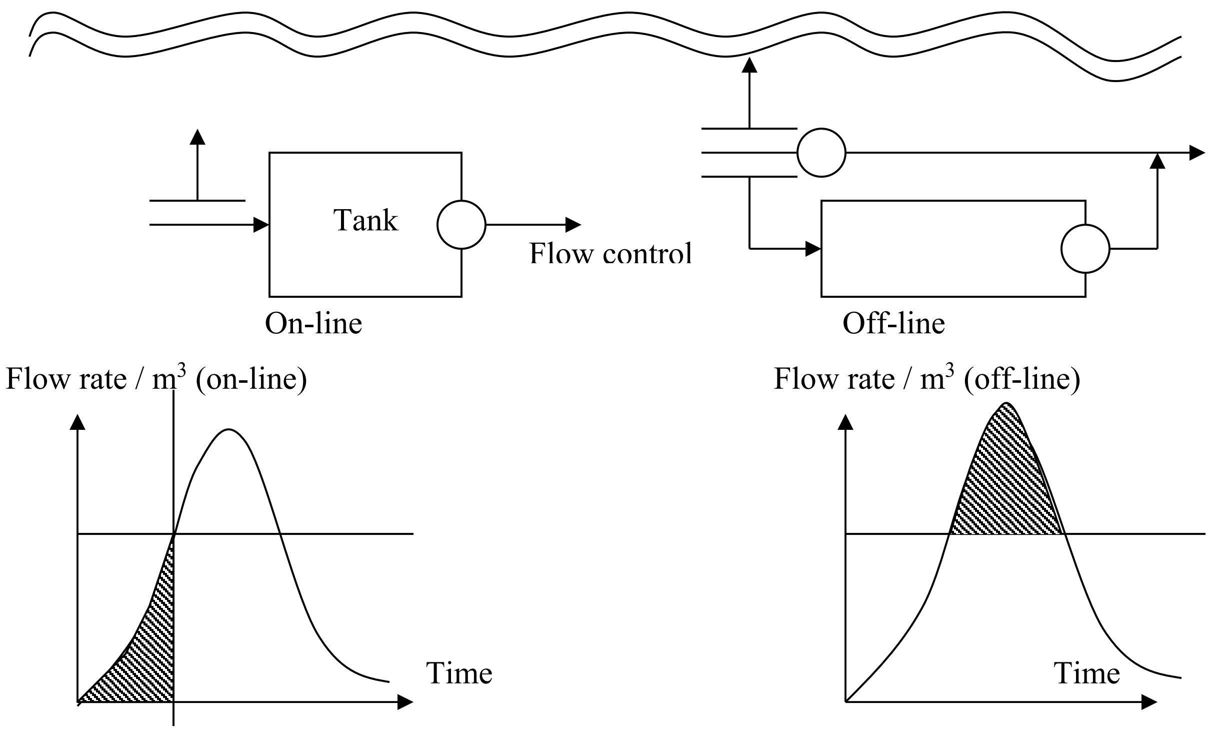

Figure 2.10 On-line and Off-line Tanks

Ponds

Surface ponds are used with reasonably uncontaminated flows. They are classified as wet or dry depending on whether a permanent pool of water is maintained.

Dry ponds are depressed areas which store runoff during storm events.
Most dry ponds are off-line and they are smaller than wet ponds. Actually, dry ponds are used to reduce the peak flow resulting from selected design storm (i.e., 10 year storm) to the predevelopment level to prevent downstream flooding. However, the efficiency of dry pond in removing pollutants is low. It is because many pollutants do not have enough time to settle out of the runoff due to of the short detention times. Furthermore, if they

does settle to the bottom, they still easily resuspended by the next storm event. Thus, they are basically used for controlling quantity instead of quality. (Field et al., 1993)

Wet ponds function, by maintaining a permanent pool, allow particulate pollutants to settle out and dissolved pollutant to be removal by biological uptake or other decay processes. Therefore, they can control in pollution and enhance the water quality of the outflow. The wet pond is shown in Figure 2.11. The depth of the pond is usually limited to 1.5 – 3.0 m to avoid thermal stratification (Lawrence et al., 1996). Shallow side-slopes and dense marginal vegetation help ensure safety.

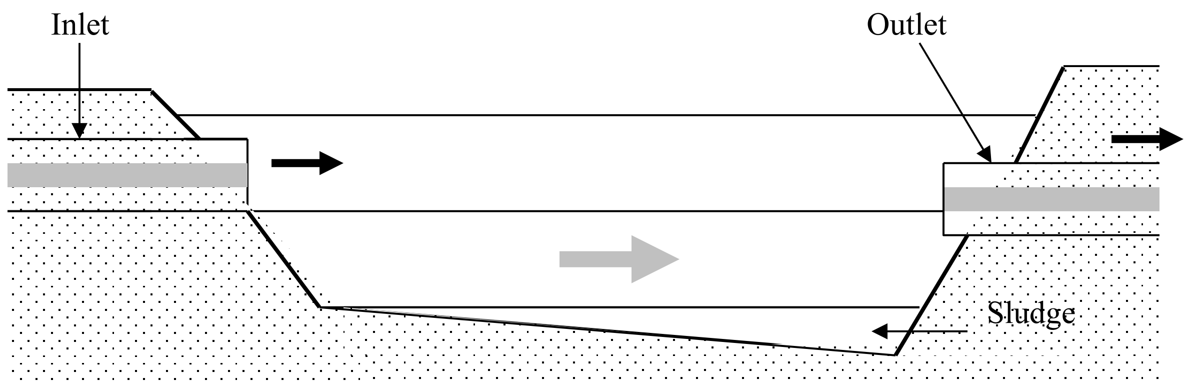

Figure 2.11 Simplified Wet Detention Pond

Combination of the two pond types which is known as dry / wet pond can also be used for water quantity control. The part of the storage area contains water at all times, and part only fills at times of high flow. "Extended" detention basins, for instance, often have a permanent pool in incorporated for aesthetic reasons.