# USER–FRIENDLY DETENTION POND DESIGN :

# DEVELOPMENT USING VISUAL BASIC 6.0

By

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# ABSTRAK

Kini, urbanisasi yang giat di banyak negara membangun, termasuk Malaysia, mendatangkan banyak krisis alam sekitar. Ini berlaku akibat lebihan air larian telah menjejaskan kualiti sungai, tasik dan sumber air yang lain. Memandangkan keadaan genting ini, projek tahun akhir ini telah dicadangkan di mana ianya berkisar kepada cara efektif dalam menguruskan air larian. Amnya, projek ini berfokus pada pembangunan model rekabentuk kolam tahanan basah jenis komuniti, dengan menggunakan *Visual Basic 6.0*. Model rekabentuk ini telah dikendalikan mengikut spesifikasi yang tertera dalam Manual Saliran Mesra Alam 'MSMA' (JPS, 2000). Dengan kata lain, model ini dibangunkan agar sesuai dengan keadaan cuaca di Malaysia. Disebabkan simulasi rekabentuk kolam tahanan melalui model ini hanya untuk menampung kawasan tadahan 80 ha dan ke atas, maka Cara Masa-Kawasan dicadangkan untuk menganggarkan aliran masuk puncak dan aliran keluar puncak. Setelah hubungan paras-storan dan paras-buangan ditentukan, *Level-Pool Routing* digunakan untuk mendapatkan aliran keluar puncak dari kolam tahanan. Ini adalah untuk memastikan air yang dilepaskan tidak akan membanjiri kawasan di hilir sungai. Untuk menentukan ketepatan output rekabentuk melalui model ini berbanding dengan *EXCEL*, ianya telah digunakan untuk merekabentuk kolam tahanan basah dalam kawasan pembangunan Mukim 6, Daerah Seberang Perai Utara, P. Pinang. Kadar alir masuk dan kadar alir keluar dibenarkan, serta saiz kolam tahanan yang diperoleh melalui model ini terbukti lebih kurang sama dengan kiraan *EXCEL*. Namun, yang berbeza hanyalah kadar alir keluar daripada kolam tahanan. Secara keseluruhannya, model ini masih merupakan alat yang berkesan semasa membuat rekabentuk awalan untuk kolam tahanan basah.

# ABSTRACT

Nowadays, urban development in many developing countries, e.g. Malaysia, has found susceptible to adverse environmental crisis through excessive runoff that leads to the degradation of rivers and lakes. Therefore, this project has been carried out in which effective way to manage stormwater has to be developed. Actually, this project is focused more on the development of community and regional detention pond design using Visual Basic 6.0. In accordance with the guidelines provided in Urban Stormwater Management Manual for Malaysia 'MSMA' (DID, 2000), a computer model had been developed under this final year project. In other words, this model is built specifically to suit the design rainfall in Malaysia. Since the detention pond simulated via this design model is only to cater for large catchment area ( 80 ha and above ), hence, the Time-Area Method is proposed for the estimation of peak inflow and outflow. After attaining both the stage-storage and stage-discharge relationships, Level Pool Routing will then be used in order to determine the peak discharge once a detention pond is designed. This is to ensure that the runoff discharged from the detention pond will not overflow the receiving water downstream. Even the manual calculation had been conducted to have this model checked and complemented. To verify its computation accuracy compared to spreadsheet (EXCEL), this model had been used to design the proposed wet community and regional detention pond located in a development area in *Mukim 6, Daerah Seberang Perai Utara, P. Pinang.* All the inflows, allowable outflows and required detention pond storage computed through this model were proved to be almost the same as that of EXCEL, only the outlet discharge is rather different between the two. As a whole, this model is indeed a helpful tool to do the preliminary design of wet detention pond.

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# CHAPTER 1: INTRODUCTION

## 1.1 ) Issues of Current Development

Many bad-ridden issues drawn by stormwater have been arising due to the unplanned aggressive urbanization. Generally, the landuse changes from rural to urban or industrial areas cause local runoff impacts on receiving water flow, quality and ecology. Associated with erosion and sedimentation problems, stormwater has obviously contributed to receiving waters a significant load of pollutants, likely to be phosphorous, nitrogen, heavy metals, oil and grease, bacteria, etc.

Consequently, the rivers, lakes, reservoirs and coastal waters have become sensitive to increased rates and volumes of runoff, and pollutant discharges as well. This phenomenon has posed environmental issues to many urbanized areas in West Coast of Peninsular Malaysia, especially in Klang Valley. Frequent intense rainfalls and poor planned urbanization also do make the condition worse.

Realizing the needs to switch to a new and broader urban stormwater management approach, in view of the nation's progressive development at tremendous pace, conventional storm drainage system has subsequently been abolished. Hence, to date, every professional indulged in stormwater management should, should not only to design satisfactory flood protection facilities, but also to control and reduce stormwater pollution within urban catchments and in receiving waters.

## 1.2 ) Objectives of The Project

This project, entitled User-Friendly Detention Pond Design, will be conducted using computer programming language, Visual Basic 6.0. Since the needs of this kind of pond are overwhelming for the construction projects of new era, all drainage engineers and fresh graduates should better equip them with relevant knowledge in such water impounding facilities. The main objectives of this modeling project are to develop a Windows based program for the beginners of detention pond design, and to complete their task in a flick of time. This is to ensure a more systematic and sequential design to be easily grabbed by learners, instead of using spreadsheet which relies on quarterly manual manipulation.

Parts with the main objectives mentioned above, below are sub-objectives that can be achieved by the Visual Basic program automation functions:

- To determine the time of concentration of surface runoff for pre and post development.
- To determine rainfall of every storm duration for selected ARI.
- To determine critical storm duration and corresponding inflow volume.
- To determine required detention pond area and check its suitability using stage-storage relationship.
- To design either single or multi-stage stormwater control structure.
- To estimate the sizing of primary and secondary outlet facilities using stage-discharge relationship.

- To determine peak discharge and peak water level due to critical storm duration through routing process.
- To perform different calculation to compare peak discharge cum water level yielded, if different outlet combination is used.
- To obtain the most desirable dimension and properties of detention facilities, if cost-effectiveness and proper design life were taken into consideration.

## 1.3 ) Scope of The Project

Since large areas of impervious areas during urbanization can lead to numbers of adverse impacts, it is necessary to quantify the related impacts and to develop action plans and measures to address them. Thus, during the project detention pond design, many aspects have to be taken into account, like what had been cited in MSMA. These are being shown as below:

i.) General Outline

Before commencing the design, it is vital to know the geographic and hydrological conditions encountered in Malaysia, arisen current development issues, drainage system practices, and the latest guideline for stormwater management in Malaysia. Then, only baseline data can be obtained for subsequent design process.

ii.) Hydrology and Hydraulics

Hydrologic design concepts, for instance, the difference in approach between stormwater quantity control measures and quality control measures, have to be made clear.

Furthermore, which of the fundamental hydraulic concepts and flow formulas are essential should be determined. Based on MSMA, present methods and procedures for detention pond size estimation and outlet configuration are shown, with the rainfall design data for Malaysia provided.

iii.) Runoff Quantity Control

The impacts of urban development on runoff quantity can be addressed using a range of on-site, community and regional scale detention facilities. However, for this project, only community and regional detention facility will be focused. To do so, the requirements and considerations for that particular facility are to be ascertained before proceeding to further design.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 ) Overview of Study

Under the topic of urban stormwater management, this final year project will be conducted with the supporting ideas from various sources such as electronic journals, reference books and design manuals. Due to the less emphasis of stormwater management during development projects, many problems have occurred, namely flash floods, water pollution, urban slope failures and etc.

According to Urban Stormwater Management Manual for Malaysia (DID, 2000), urban stormwater management is vital to restore each component of the hydrological cycle to its natural level. However in actual case, it is hardly to be achieved. There are several objectives in order to uphold the practices of responsible stormwater management. For instance, it is to minimize and control nuisance flooding, minimize the runoff impact on water quality, and the most important is to optimize the land available for urbanization.

Water has becoming scarce due to the ever-growing of population. Hence, there appear tendencies to utilize the local water source such as urban stormwater and groundwater. In this case, stormwater should be regarded as natural assets to be valued. To date, the conveyance approach which promoted the disposal of stormwater as fast as possible has been gradually replaced by storage-oriented approach, especially to control urban runoff in many areas (DID, 2000). In the context of detention purposes, the objective of this approach is to provide temporary storage of urban runoff at or near its point of origin with subsequent slow release to downstream.

In parallel with the aim of minimization of flood damage and for the runoff to be stored and reused as non potable water supply, such as for irrigation and domestic purposes, detention pond is the most appropriate solution to it (Behera, 1999). There are 3 types of detention facilities suggested by DID (2000) as follow:

- on-site storage, which comprising small storages constructed on residential, commercial and industrial lots
- community storage, which is a large facility constructed in public open space areas for recreational purposes
- regional storage, a large scale community facilities constructed at the lower end of catchment prior to discharge to receiving waters via storage within lakes and reservoirs

In general, on-site detention is aiming to reduce nuisance flooding in the surrounding local area whilst community and regional detention is to increase public safety and minimize property damage in the downstream catchment and receiving waters.

Guo (2001) stated that in urban areas, the installation of storm sewers and realignment and channelization of streams might result in a more rapid transmission of surface runoff. Furthermore, rainfall events of different magnitudes will cause various degrees of flooding downstream. Thus, detention facilities should be designed to reduce peak flow rates from inconsistent storm events. But according to Stahre (1990), it is not enough to address only hydraulics and hydrology when designing detention pond. This is because successful detention facilities should also have great recreational and other community uses.

## 2.2 ) Fundamentals of Design

i.) Design ARI

As indicated in MSMA (DID, 2000), Average Recurrence Interval (ARI) is the average elapsed time in years between floods of a given area occurring. This means that for a flooding which is rarely occurs on average once after a longer interval, it would have a relatively larger ARI value. Furthermore, as quoted from James (1982), the idea of design storm is to provide a means of estimating discharge of ARI for planning and design purposes.

For the sake of efficiency in detention facilities, it is suggested that outlets should control the flows of at least 2 recurrence frequencies of runoff (Urbonas, 1990). This is due to the fact that control of two widely different recurrence frequencies of storms can control runoff of other recurrence frequencies as well. In actual condition, design storm ARIs are being stipulated in urban stormwater system design manual by local authorities in most countries worldwide, like what is being shown in Table 2.2.1.

**<u>Table 2.2.1 : Design Storm ARIs for Urban Stormwater System</u> (DID, 2000)**

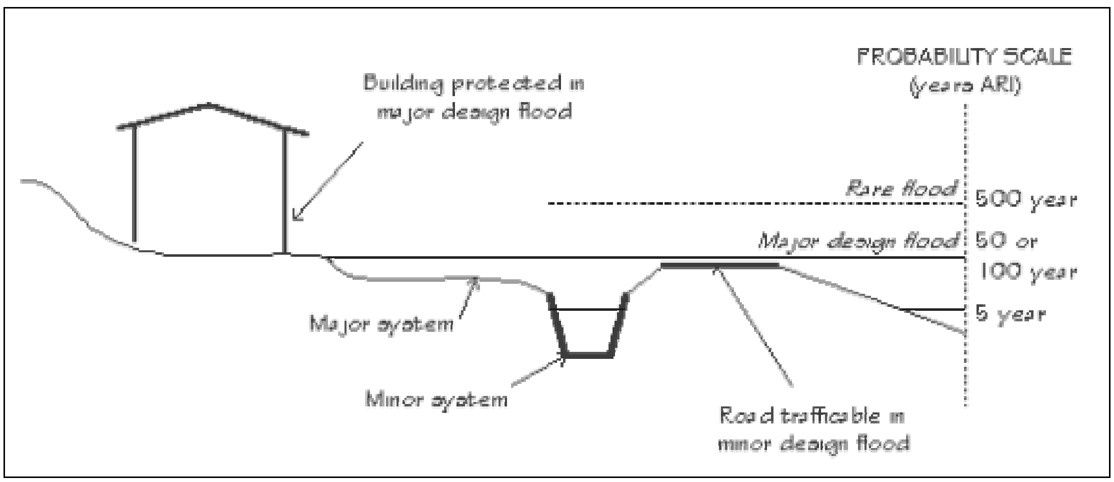
| Type of Development | ARI of Design Storm ( year ) | | |
|---|---|---|---|
| | Quantity | | Quality |
| | Minor System | Major System | |
| Open space, Parks, Agricultural Land | 1 | up to 100 | 3 month ARI ( for All Types of Development ) |
| Residential : | | | |
| Low Density | 2 | up to 100 | |
| Medium Density | 5 | up to 100 | |
| High Density | 10 | up to 100 | |
| Commercial, Business & Industrial ( Not in Central Business District ) | 5 | up to 100 | |
| Commercial, Business & Industrial ( in Central Business District ) | 10 | up to 100 | |

According to Guo (2001), to apply the design storm approach, assumption has to be made that a storm as a whole, may have a certain return period. Therefore, the peak discharge rate of runoff generated from the storm will have the same return period. Normally, the selection of design storm ARI relies on the economic factor. However, as stated in MSMA (DID, 2000), the economic factor is typically replaced by the concept of level protection. However, if this does not work, ARI should be adjusted to optimize the ratio cost to benefit or social factors.

ii.) Major & Minor System Design

As being cited in MSMA (DID, 2000) design approach, both major and minor systems should be planned to enable the design conformity on natural drainage patterns where discharge is being drawn to natural drainage paths within a catchment. However, for this project to develop a model for designing community and regional detention pond, only major system will be taken into consideration.

Major system, can be defined as a system that provides overland relief for runoff exceeding the capacity of minor system. It is composed of natural pathways or artificial receiving channels such as streams, creeks or rivers, aiming to protect the community from the consequences of large, reasonably rare flooding which causes severe loss of properties and lives. In Malaysia, recommended major design storm standard for major system is up to 100 year ARI. In contradictory to major system, minor system is also intended to collect and convey runoff but this time, runoff is from relatively more frequent storm events. The minor system may be made up from any combination of piped or open drains, etc. The illustration to show the difference between major and minor system is shown below.




**<u>Figure 2.2.1 : Major and Minor System Design Concepts</u> (DID, 2000)**

iii.) Quantity & Quality Design

Guo (2004) viewed that detention pond is meant to control both the runoff quantity and quality from a catchment, and is henceforth more generally denoted as stormwater management (SMW) pond. But for this project, the model development of detention pond design is only based on storage-oriented approach and quantity design.

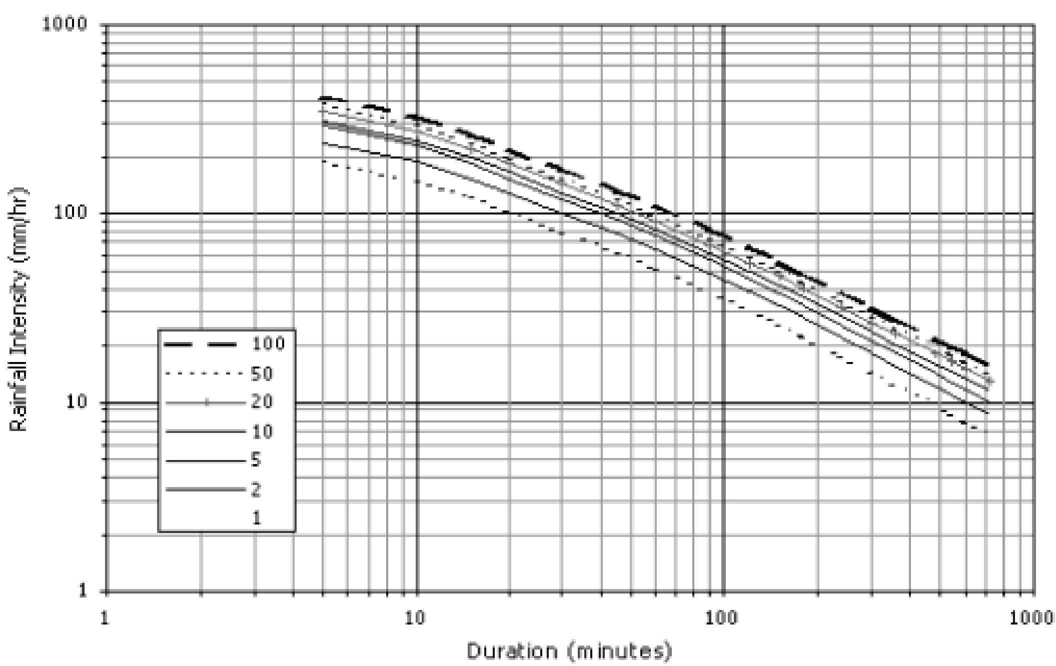
Quantity design is tackling with sizing of structures for collecting, conveying, controlling, and disposing of stormwater runoff. As indicated in MSMA (DID, 2000), during the computation discharge from the design storm, allowance should be made for any reduction in discharge due to quantity control measures installed, e.g. detention facilities. Consideration taken for quantity design such as runoff peak discharge, management of infrequent storms, etc, are of utmost importance in order to derive the maximum permissible dimension of necessary runoff control structures at any ARI event for both minor and major system.

iv.) Design Rainfall

As everyone is well concerned, rainfall is important to attain the design storm duration, which serves to be an important parameter that defines the rainfall depth or intensity for a given frequency before contributing to the resultant runoff peak and volume. Based on MSMA (DID, 2000), there are 2 types of recognized design storm, namely synthetic and historic storms. However for this project, synthetic design storm will be used for urban stormwater system, whereby synthesis and generalization of a large number of actual storms is required for its derivation. The design storm duration, which is equal or longer than the time of concentration for the catchment will then be used for design purposes.

MSMA (DID, 2000) stated that the theoretically practice is to compute discharge of several design storms with different durations, then the critical storm which yields the maximum discharge would be used for design. However, after researches had been carried out, the so-called critical storm duration through that way may not be the most critical for detention storage design. Thus, the appropriate way should be the computation of design flood hydrograph for several storms, with the use of duration which produces the most severe effect on the pond size and discharge for design.

In practice, design storms with certain ARI are derived using the Intensity-Duration-Frequency (IDF) information (Stahre, 1990). Such IDF curves are so useful in stormwater detention design that many calculation procedures rainfall input in the form of average rainfall intensity. Figure below shows the example of IDF curves generated for Malaysia metropolitan city, Kuala Lumpur.




**<u>Figure 2.2.2 : IDF curves for Kuala Lumpur</u> (DID, 2000)**

In this project, to model a detention pond design catering for major cities in Peninsular Malaysia, many IDF curves should be used. For the purpose of getting design easier, alternative method had been worked out where polynomial expressions in the form of Equation 2.2.1 had been fitted to the published IDF curves for the 36 main cities in Malaysia.

$$\ln({}^{R}I_{t}) = a + b\ln(t) + c(\ln(t))^{2} + d(\ln(t))^{3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.2.1)}$$

Where, ${}^{R}I_{t}$ = 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

The equation above can be used to compute rainfall intensity for a given duration and ARI, provided that the values of coefficients $a$ to $d$ are known. However, there appears to have limitation where this equation is only valid for duration between 30 and 1000 minutes.

In accordance with MSMA (DID, 2000), an important factor that affects the runoff volume, the magnitude and the timing of the peak discharge is the temporal distribution of rainfall within the design storm. In this context, design rainfall patterns are used to represent the typical variation of rainfall intensities when the storm bursts. Following are the rainfall standard duration and its temporal patterns recommended by MSMA (DID, 2000) for Peninsular Malaysia.

**Table 2.2.2 : Standard Duration for Urban Stormwater Storage System**

**(DID, 2000)**

| Standard Duration ( minutes ) | Number of Time Intervals | Time Interval ( minutes ) |
|---|---|---|
| 10 | 2 | 5 |
| 15 | 3 | 5 |
| 30 | 6 | 5 |
| 60 | 12 | 5 |
| 120 | 8 | 15 |
| 180 | 6 | 30 |
| 360 | 6 | 60 |

**Table 2.2.3 : Temporal Patterns for Peninsular Malaysia (DID, 2000)**

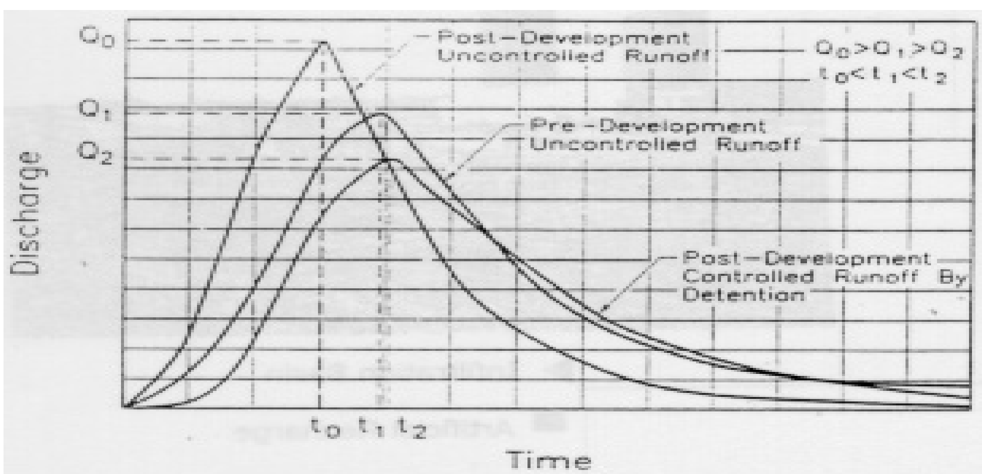
| Duration (minutes) | No. of Time Period | Fraction of Rainfall in Each Time Period | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 2 | 0.570 | 0.430 | - | - | - | - | - | - | - | - | - | - |
| 15 | 3 | 0.320 | 0.500 | 0.180 | - | - | - | - | - | - | - | - | - |
| 30 | 6 | 0.160 | 0.250 | 0.330 | 0.090 | 0.110 | 0.060 | - | - | - | - | - | - |
| 60 | 12 | 0.039 | 0.070 | 0.168 | 0.120 | 0.232 | 0.101 | 0.089 | 0.057 | 0.048 | 0.031 | 0.028 | 0.017 |
| 120 | 8 | 0.030 | 0.119 | 0.310 | 0.208 | 0.090 | 0.119 | 0.094 | 0.030 | - | - | - | - |
| 180 | 6 | 0.060 | 0.220 | 0.340 | 0.220 | 0.120 | 0.040 | - | - | - | - | - | - |
| 360 | 6 | 0.320 | 0.410 | 0.110 | 0.080 | 0.050 | 0.030 | - | - | - | - | - | - |

Temporal patterns from local IDF relationships above are used to distribute rainfall within a design storm. Assumption has been made that the maximum rainfall for any duration less than or equal to the total storm duration should have the same ARI. Though there are some theoretical flaws to this approach, but since it combines several peaks from different historical storms. Owing to its logistics and convenience for design, it is therefore widely used for urban stormwater management system.

### 2.3 ) Design Criteria for Detention Pond

i.) Principles of Quantity and Quality Control

Stormwater quantity control facilities basically can be classified through their function, as either detention or retention facilities. As Chin (2000) mentioned, quantity control is usually needed to bring down the peak post-development runoff rates, so as to not exceed peak pre-development runoff rates during any design rainfall. Many studies indicated that detention facilities can reduce the frequency and extent of downstream flooding, by reducing the peak cum volume of runoff from a given catchment. The results of the then researches are being shown as below:




**<u>Figure 2.3.1 : Hydrograph Showing Uncontrolled Runoff & Controlled Runoff by Detention for Pre and Post-Development</u> (DID, 2000)**

Currently detention pond is becoming more generally used, not only for water quality control, but also for provision of temporary storage and release of runoff through uncontrolled outlet (Larry, 2001). There are 2 general types of detention ponds, known as wet pond and dry pond. Wet detention pond is an impoundment where a water body forms the base of the storage area, while that impoundment where ground surface grounds the base of storage is called dry detention pond.

Considering aspect of quality control, the quality of urban runoff is being maintained through source control and treatment control (Chin, 2000). Source control is defined as a measure that prevents the pollutants from entering the runoff. Meanwhile treatment control, be it detention pond or infiltration basin, is measure that removes pollutants from the runoff. Wet detention pond is used to remove pollutants through physical, chemical and biological processes. In contrast, dry detention basin removes pollutants mostly only by sedimentation.

When it comes to decision on which type of detention pond to be used for quality control, it relies on the requirement for nutrient removal. It is of utmost importance when the quality of receiving water is sensitive to nutrient loadings. According to Larry (2001), wet detention pond does provide more nutrient removal than dry detention pond. This is due to the fact that nutrients in former runoff are in dissolved forms without significant effects incurred during the sedimentation process in dry detention pond. Nevertheless, greater land is required for the construction of wet detention pond compared to that of dry detention pond, whereby 2 to 7 times more storage is needed than the latter.

Referring to Guo (2004), both hydrology and hydraulic information are essential for the design of a detention pond. The basic hydrologic data includes the inflow hydrograph and the allowable rate of release. Meanwhile the hydraulic information requires prior knowledge regarding the basin geometry and outlet structures. Notwithstanding the little hydraulic information, stage-discharge and stage-storage curve should be derived during a feasibility study and planning before proceeding to construction stage.

To ensure that the detention pond will meet the critical runoff objectives, the behavior of the storage of the will-be-constructed pond should be considered by examining the following (DID, 2000):

- the degree of flow reduction from the catchment
- the depth of ponding and its duration
- the frequency when the secondary outlet and the embankment start operating

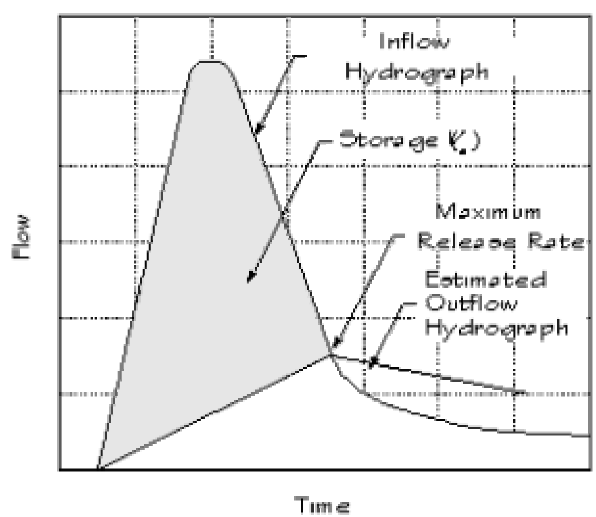
Design and analysis that follow suit after the processes above are stated below:

1. hydrological computation to determine the runoff to be handled
2. hydraulic computation to route the flows through the storage for the determination of runoff reduction, and
3. geotechnical and structural design

ii.) Conceptual Design for Detention Pond

Initially, to design a detention pond, its sizing of detention facilities must be planned coincides with the routing algorithm. Like what had been proposed by Malcom (1982), routing process requires 3 sets of data, ranging from inflow hydrograph, stage-storage relationship and stage-discharge relationship. Having to say, the derivation of these two basin characteristic curves needs vast knowledge concerning the basin shape, outlet structure as well as tailwater.

Before the sizing of detention pond taking place, preliminary storage volume to attenuate the peak runoff should be estimated. This is said to be vital from MSMA (DID, 2000), so as to reduce the number of trials involved in the sizing procedure. Based on the post-development condition for major design ARI, inflow hydrograph over a range of durations should be ascertained and the maximum estimated volume is selected. Diagram below illustrates on how the estimated basin storage is attained via hydrograph method. To make things simpler, the following regression equation for each estimated inflow hydrograph can be used.




**<u>Figure 2.3.2 : Preliminary Estimation of Required Basin Volume</u> (DID, 2000)**

$$V_s = 1.291 V_i \left[ 1 - \frac{Q_0}{Q_1} \right]^{0.753} \left[ \frac{t_i}{t_p} \right]^{-0.411} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.3.1)$$

Where, $V_s$ = estimated storage volume ($m^3/s$)

$V_i$ = inflow hydrograph runoff volume ($m^3/s$)

$Q_i$ = inflow hydrograph peak flow rate ($m^3/s$)

$Q_0$ = allowable peak outflow rate ($m^3/s$)

$t_i$ = time base of the inflow hydrograph (minute)

$t_p$ = time to peak of the inflow hydrograph (minute)

Meanwhile, guidelines in MSMA (DID, 2000) do spell out that the needs of inflow hydrographs for a range of design storm durations to be routed through the basin, in order to determine the maximum storage volume and water level corresponding to the maximum permissible outflow rate. However, manual calculation methods would be time-consuming due to the complexity of calculations and the number of hydrographs that need to be estimated and routed. Hence, computer aid modeling is much preferred.

Malcom (1982) indicated that the stage-storage relationship models the depth of water relating to the size and shape of storage container. The storage volume for detention basin in irregular terrain may be developed using a topographic map or the double-end area method, with its formula being shown as below.

$$V_{1,2} = \left[ \frac{(A_1 + A_2}{2} \right] \Delta d \quad \text{.........................................} \quad (2.3.2)$$

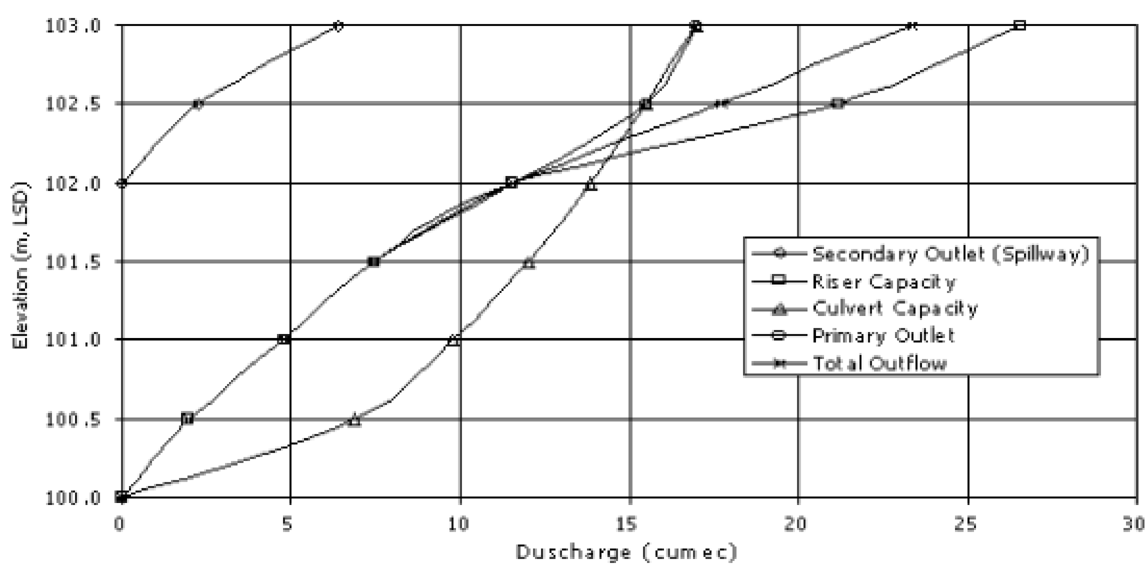
Where, $V_{1,2}$ = storage volume between elevation 1 and 2 ($m^3$)

$A_1$ = surface area at elevation 1 ($m^2$)

$A_2$ = surface area at elevation 2 ($m^2$)

$\Delta d$ = change in elevations between point 1 and 2 (m)

Next, the storage-discharge relationship that exhibits the hydraulic characteristics of the outlet device has to be determined (Malcom, 1982). In other words, the stage-discharge curves define the relationship between the basin water depth and the outflow from a storage facility. For a better design, a single composite stage-discharge curve should be developed for each design storm outlet management. Figure below illustrates the stage-discharge curve for an outlet device comprising low flow orifices on a riser pipe connected to a pipe culvert.

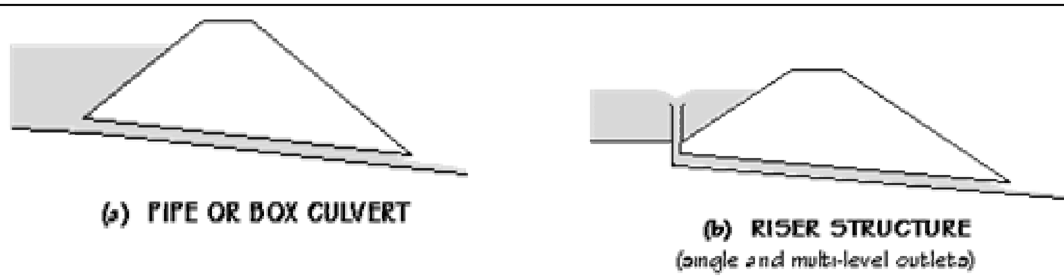



**<u>Figure 2.3.3 : Composite Stage-Discharge Curve</u> (DID, 2000)**

iii.) Outlet Design Perspective

Guo (2004) suggested that within the detention basins, there should have conveyance facilities such as pipe and channels, to be placed at strategic locations in order to attenuate the peak runoff. There are two outlets to be considered fro detention pond design, known as primary outlets and secondary outlet.

In the context of primary outlets, a two-staged outlet is required, for one outlet is configured to control the minor system design ARI flow whilst another outlet is to control the major system design ARI flow (DID, 2000). These basin outlets are normally uncontrolled. For single stage system, the facility is usually in the form of a simple culvert structure. But for multi-staged system, the design runoff flows is supposedly to be orifice flows and when it comes the heavier storm, the higher flows will become weir flow over the top of the riser, for most cases. The riser is then connected to a single conduit that passes through the basin embankment before discharging to the downstream receiving waters. Following are the schematic diagrams of typical primary outlets.




**<u>Figure 2.3.4 : Typical Detention Pond Primary Outlets</u> (DID, 2000)**

Meanwhile, the purpose of secondary outlet, or specifically noted as emergency spillway, being designed is to provide for detention basin a controlled overflow for runoff whenever the maximum design storm 100 year ARI is exceeded (DID, 2000). The emergency spillway is designed to pass flows in excess of the design storm, as mentioned earlier, without overtopping of the embankment. This is due to the fact that the embankment, which is simply made of fill material, will not be able to sustain the high pressure imposed by the high level of water. To make analysis easier, a high spillway level is a necessity to ensure a higher water level detained during the over-limit maximum design storm or when the outlets were plugged with debris (Urbonas, 1990). A spillway is only suitable for big scale detention pond particularly the community and regional detention pond. This is because the construction cost is high and impractical to have spillway installed in small detention pond, e.g. on-site detention pond, catering a small catchment below 80 ha.

iv.) Principles and Flow Routing Process

Routing is a process of determining the spatial and temporal variations in flow rate along a watercourse (Chin, 2000). It is indeed a process of converting a hydrograph that passes through a flow system with available changes (DID, 2000). Routing models can be classified as either lumped or distributed system. However for this project, focus will be on lumped system, by which the flow will only be calculated as a function of time. Generally, flow routing using this system is denoted as hydrologic routing.

During the detention pond design, hydrologic routing which makes use of level-pool method will be used to calculate the outflow hydrograph from a pond reservoir, with the assumption that there is a horizontal water surface having its inflow hydrograph and stage-storage characteristics. The basic equation used in level pool routing is the continuity equation as follow:

$$\frac{dS}{dt} = I(t) - Q(t) \quad \text{......................................} \quad (2.3.2)$$

Where, $S =$ pond storage

$t =$ time

$I(t) =$ inflow from the pond upstream

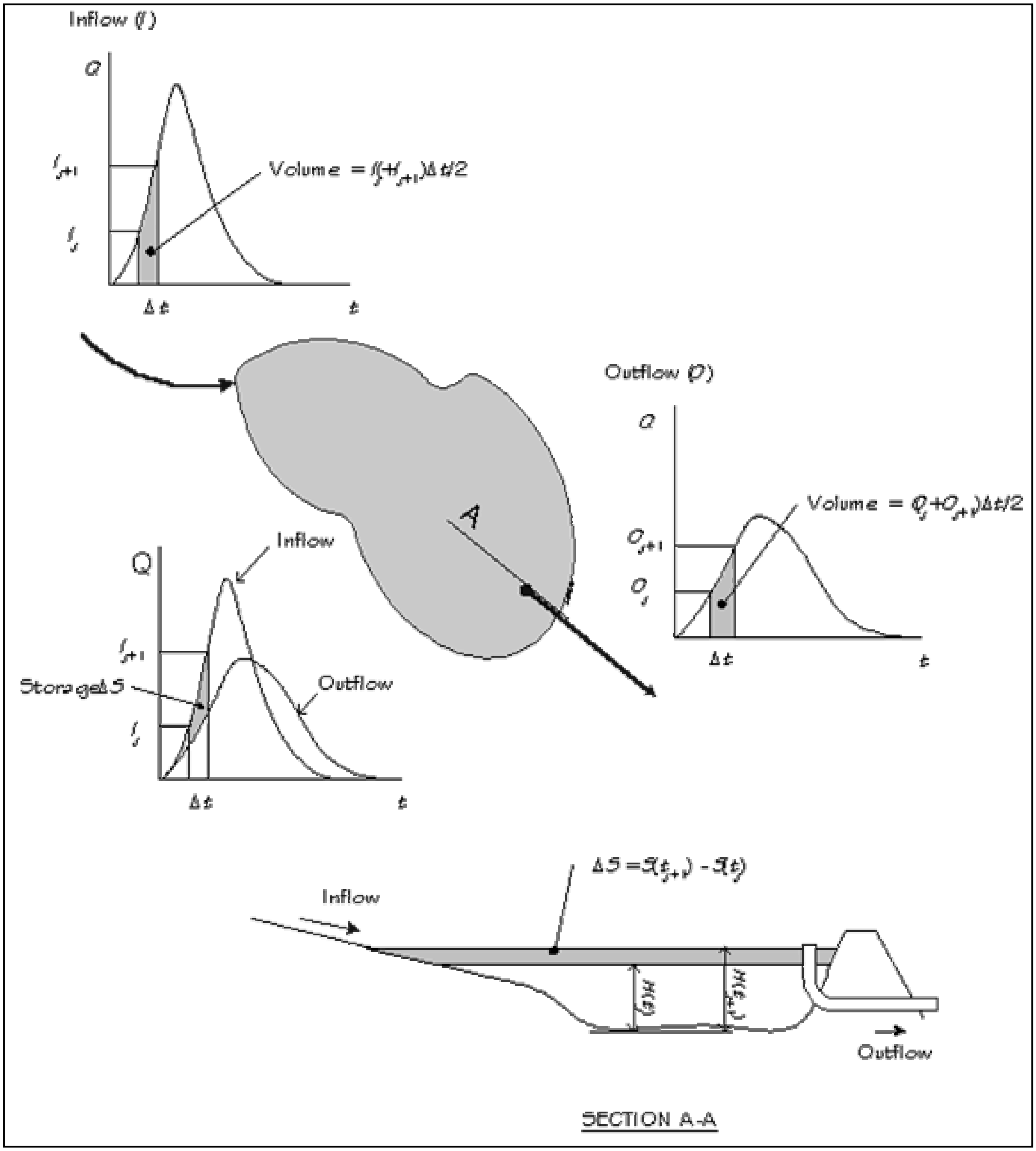
$Q(t) =$ outflow from the pond downstream

In the case of pond storage, the storage, $S$, is merely a function of the outflow, $Q(t)$. Chin (2000) recommended that the storage indication method, also called the Modified Puls Method, should be applied. Integration of Equation 2.3.2 over the discrete time intervals yields the following expression.

$$\frac{S_{j+1} - S_j}{\Delta t} = \left(\frac{I_j + I_{j+1}}{2}\right) - \left(\frac{Q_j + Q_{j+1}}{2}\right) \quad \text{......................................} \quad (2.3.3)$$

For convenience during the hydrograph routing through a pond storage, Equation (2.3.3) can be rearranged into the below. The ideas of developing this function from stage-storage and stage-discharge are originated from what have been portrayed in Figure 2.3.5.

$$\left(\frac{2S_{j+1}}{\Delta t}+Q_{j+1}\right)=(I_j+I_{j+1})+\left(\frac{2S_j}{\Delta t}-Q_j\right) \qquad (2.3.4)$$




**<u>Figure 2.3.5 : Sequences for The Development of Storage-Discharge Function for</u>**

**<u>Level Pool Routing</u> (DID, 2000)**