Bulletin
River Engineering and Urban Drainage Research Centre
Universiti Sains Malaysia

REDAC

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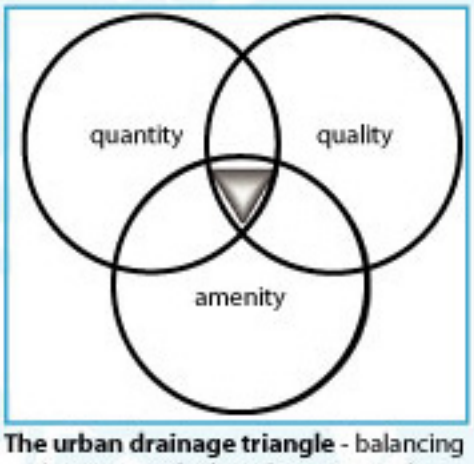
# Sustainable Urban Drainage System

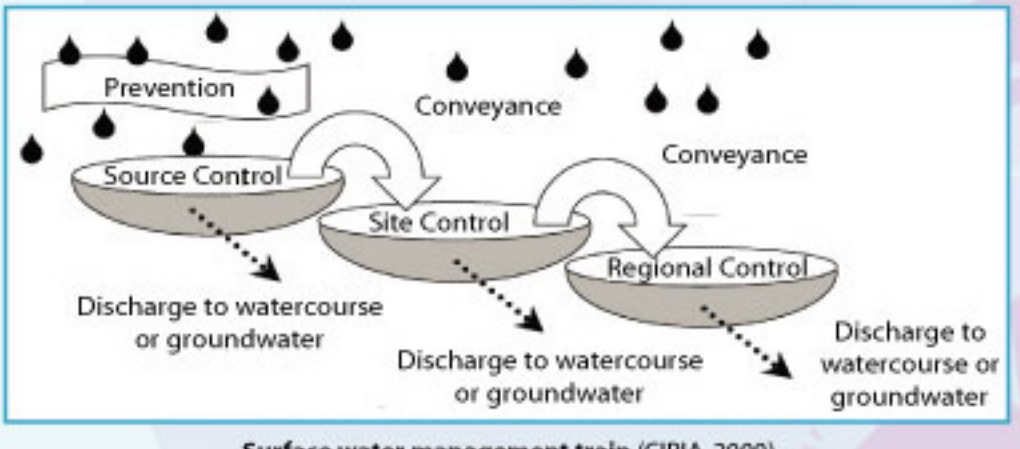
Sustainable Urban Drainage System (SUDS) is a concept that includes long term environmental and social factors in decisions about drainage. It takes account of the quantity and quality of runoff, and the amenity value of surface water in the urban environment. Many existing urban drainage systems can cause problems of flooding, pollution or damage to the environment and are not proving to be sustainable.

SUDS are made up of one or more structures built to manage surface water runoff. They are used in conjunction with good management of the site, to prevent flooding and pollution. There are four general methods of control which are filter strips and swales, filter drains and permeable surfaces, infiltration devices, wetlands, basins and ponds. The controls should be located as close as possible to where the rainwater falls, providing attenuation for the runoff. They also provide varying degrees of treatment for surface water, using the natural processes of sedimentation, filtration, adsorption and biological degradation. The surface water management train addresses the runoff quantity and quality at all stages of the drainage system (CIRIA, 2000).

Bio-Ecological Drainage System (**BIOECODS™**) at USM Engineering Campus is a pilot project in Malaysia that applies the ***surface water management train concept*** (Ab. Ghani et al. 2004). The components of BIOECODS include ecological swales (***source control***), dry ponds and wet pond (***site control***), and detention pond (***regional control***). For further water quality treatment purpose, an offline constructed wetland is provided at the downstream end (Ayub et al. 2005). Several other similar projects have also been carried out recently by the Department of Irrigation and Drainage (DID) Malaysia and the Public Works Department as highlighted in this bulletin. More SUDS projects are expected to be carried out under 9th Malaysian Plan (2006-2010) in line with aspiration of Malaysia to become a developed nation in 2020.




**The urban drainage triangle** - balancing the impact of urban drainage on the environment (CIRIA, 2000).




**Surface water management train** (CIRIA, 2000).

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Ayub, K. R., Mohd Sidek, L., Ainan, A., Zakaria, N. A., Ab. Ghani, A. & Abdullah, R. (2005). Storm water Treatment using Bio-Ecological Drainage System, International Journal River Basin Management, IAHR, Vol. 3, No.3, pp. 215-221.

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# FOREWORD

By Associate Prof Dr Nor Azazi Zakaria, REDAC Director

Sustainable urban drainage system (SUDS) is a major talking point in Malaysia with the launching of Urban Storm Water Management Manual for Malaysia **(MSMA)** in 2001. With flash floods and water pollutions as major issues to be content with, MSMA has projected SUDS as one approach that can solve both problems. Universiti Sains Malaysia (USM) has lead the research on SUDS in Malaysia and South-East Region through its research centre, REDAC. Bio-Ecological Drainage System **(BIOECODS™)** is the SUDS pilot project in Malaysia and worldwide encompassing all tools under surface water management train concept including swales, dry ponds, wet pond, detention pond, wetland, wading river and recreational pond. Many researchers, postgraduate students and engineers have visited **BIOECODS™** project at the USM Engineering Campus, Nibong Tebal since its completion in 2001. Local and overseas visitors are welcome to USM Engineering Campus to seek the uniqueness of **BIOECODS™**.

Two recent projects on SUDS i.e. Rehabilitation of Ex-Mining Ponds and Existing Wetland for Integrated Storm water Facilities at Ipoh, Perak and **BIOECODS™** at Taiping are discussed in details in this bulletin. These two projects represent a continuing effort by relevant agencies in Malaysia such as the Department of Irrigation and Drainage **(DID)** Malaysia and the Public Works Department **(JKR)** in projecting SUDS as a major approach in solving flash flood and water pollution woes in urban areas. REDAC has been appointed as consultants for both projects confirming USM as the leader in the field of SUDS in Malaysia.

REDAC is also planning to offer an MSc mixed-mode postgraduate programme called the **"Sustainable River Management"** starting in **2007/2008 academic year.** The programme will run for one year with five courses offered in the first semester including River Management, Urban Drainage Management, River Modeling, Urban Drainage Modeling and Management of River Ecosystems. A research project will be conducted in the second semester based on the on-going research conducted by REDAC.

Equipped with experience and resources on sediment transport data and SUDS applications in Malaysia, several short courses and seminars will be held continuously including Urban Storm water Management Short Course **(USWM™)** and River Management Seminar **(RiverM™).** REDAC is also planning to organize the 2nd International Conference on Managing Rivers in the 21st Century **(Rivers'07™)** in August 2007.

With the launching of the 9th Malaysia Plan in March 2006, REDAC will sign a memorandum of understanding (MOU) with DID, the third of such MOU since 1999. Among projects to be conducted under this third MOU are the review of flood mitigation project (River Muda, Kedah), Drainage Master Plan, and SUDS project. The breaking ceremony will be held at the Ipoh project to solemnize the third MOU enhancing the collaboration between USM and DID.



## CONTENTS



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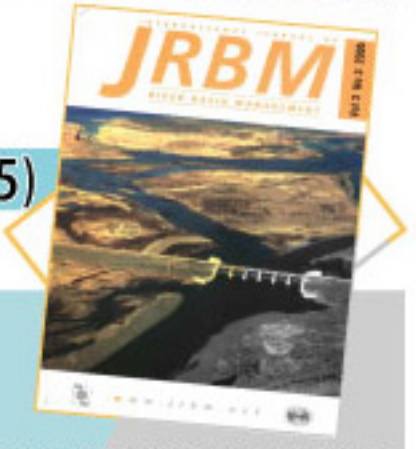
# PUBLICATION




## JRBM Special Issue Rivers'04 (Vol. 3 No. 3 2005)

### Sustainable Management of Rivers in Malaysia: Involving All Stakeholders

**Chan Ngai Weng**

**Special Issue Rivers'04, International Journal River Basin Management, IAHR & INBO**

Vol. 3, No. 3, pp. 147-162, September 2005

**Abstract:** All over the world, including Malaysia, management of rivers is a central issue in this 21st Century. While government has always been traditionally entrusted with the responsibility of managing rivers, increasingly, the public, NGOs, industrialists, farmers, and other stakeholders are playing a greater role. Sustainable management of rivers involves cooperation between countries and states sharing the same river basin, and cooperation between government and all stakeholders. Internationally, countries need to negotiate and use rivers as the basis for peace rather than conflict. In Malaysia, the Federal Government can initiate policies and remain in charge of governance of rivers, in consultation and cooperation with state governments. However, government must relinquish some of its responsibility on river management to all other stakeholders, viz. industrialists, entrepreneurs, farmers, communities/squatters, NGOs, educational institutions, fishermen, conservationists, tourists, the general public, etc. All stakeholders need to start taking proactive actions, even sacrifices, to manage, protect, conserve and restore our rivers so that their resources can be sustained for future use. This is where people from all levels ranging from politicians, policy makers, private companies, NGOs to individuals can play crucial roles. River management and related river issues need to involve NGOs and the people as these issues happen at the local level. Decision-making regarding solutions should be carried out at the lowest appropriate level, ideally involving all stakeholders ranging from government to the private sector, NGOs, the local community and schools. People should be the focus both in decision making as well as active "workers" involved with restoration work. The motto of "Malaysia Boleh" (Malaysia Can) involves all Malaysians.. This paper discusses how all stakeholders can contribute by working together in smart-partnerships with government towards effective and sustainable management of rivers in Malaysia.

**Keywords:** Non-Governmental Organisations; sustainable river management; government-industry-NGO partnerships; public participation; environmental conservation; drought and flood management; political-economy of rivers.

### Sediment Transport Equation Assessment for Selected Rivers in Malaysia

**Chang Chun Kiat, Aminuddin Ab. Ghani, Nor Azazi Zakaria, Zorkeflee Abu Hasan and Rozi Abdullah**

**Special Issue Rivers'04, International Journal River Basin Management, IAHR & INBO**

Vol. 3, No. 3, pp. 203-208, September 2005

**Abstract:** This paper describes a total of 122 sediment data obtained from May 2000 until October 2002 at Kinta River Catchment in the river sediment collection and analysis project. Data collection including suspended load, bed load, bed material and flow discharge have been carried out at six study sites consisting of four rivers which are situated at Kinta River Catchment, namely Kinta River, Pari River, Raia River and Kampar River. The sediment transport equation assessments have been carried out using Yang, Engelund & Hansen, Ackers & White and Graf equations. The results of Yahaya (1999) and Ariffin (2004) studies for Kerayong River, Kulim River and Langat River catchment (224 sets of data) are also included in this present study.

**Keywords:** Sediment transport, alluvial river, flood mitigation, erosion, deposition.

### Storm Water Treatment using Bio-Ecological Drainage System

**Khairul Rahmah Ayub, Lariyah Mohd Sidek, Anita Ainan, Nor Azazi Zakaria, Aminuddin Ab. Ghani and Rozi Abdullah**

**Special Issue Rivers'04, International Journal River Basin Management, IAHR & INBO**

Vol. 3, No. 3, pp. 215-221 , September 2005

**Abstract:** The treatment of stormwater as it flows through a Bio-Ecological Drainage System (BIOECODS) is the result of a complex interaction between the physical, chemical and biological processes that occur within the system. A stormwater quality monitoring programme at BIOECODS is being carried out by grab sampling method for the period of April – November 2003. Samples of stormwater are taken from ten stations along ecological swales and eight stations along ecological pond. The ecological pond (wet pond, detention pond, constructed wetland, wading river and recreational pond) which is placed downstream acting as a facility to control the storm water quantity and storm water treatment device before storm water flows into Kerian River. The ecological pond system is strategically placed at the downstream end of the BIOECODS to optimize and effectively attenuate and treat storm water runoff generated from the USM Engineering Campus development area.

**Keywords:** Bioecods; stormwater; water quality; swale; wetpond; detention pond; constructed wetland.

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# Rehabilitation of Ex-Mining Ponds and Existing Wetland for Integrated Storm water Facilities

## INTRODUCTION

Department of Irrigation and Drainage (DID) Malaysia has appointed REDAC to carry out a project on "Rehabilitation of Ex-Mining Ponds and Existing Wetland for Integrated Storm water Facilities" at DID Mechanical Section, Ipoh. In line with the implementation of the new urban drainage manual known as Manual Saliran Mesra Alam (MSMA), the Study will be a showcase for development of ex-mining ponds as storm water facilities in Perak and throughout Malaysia. The study is a pilot project that rehabilitates the ex-mining pond into multi-functional uses, which include recreational, water reuse and storm water retention purposes.

## BACKGROUND

The study area consists of DID Mechanical Section covering an area of 88 acres. The area is located on Lot 40367 River Kinta, Kinta District. The study area is situated on a former ex-mining land which consists of sandy soil and largely sparsely vegetated. The main feature of the site is the two ex-mining ponds (Figure 1) which are located in the vicinity of the buildings. There are also swampy areas (Figure 2) which stretched along the eastern border of the site and some parts of the swampy area may extend outside the study area. Drainage system in the Study area is based on rapid disposal approach which disposes the surface runoff to the roadside concrete drain prior to discharging into River Kinta via the pump station located near by. The surface runoff from the open area flows into the two main ex-mining ponds which are connected to the River Kinta by earth drain.

The ex-mining ponds and the existing wetland (swampy areas) shall be rehabilitated and restored into ecological ponds with multi-functional uses (Figure 3). The planning and design into the restoration and rehabilitation of the ecological ponds shall be based on the MSMA and fulfill the requirement of water quantity and quality control.



**Figure 1 Ex-Mining Ponds**

**Figure 2 Several Common Wetland Species in the Project Area**

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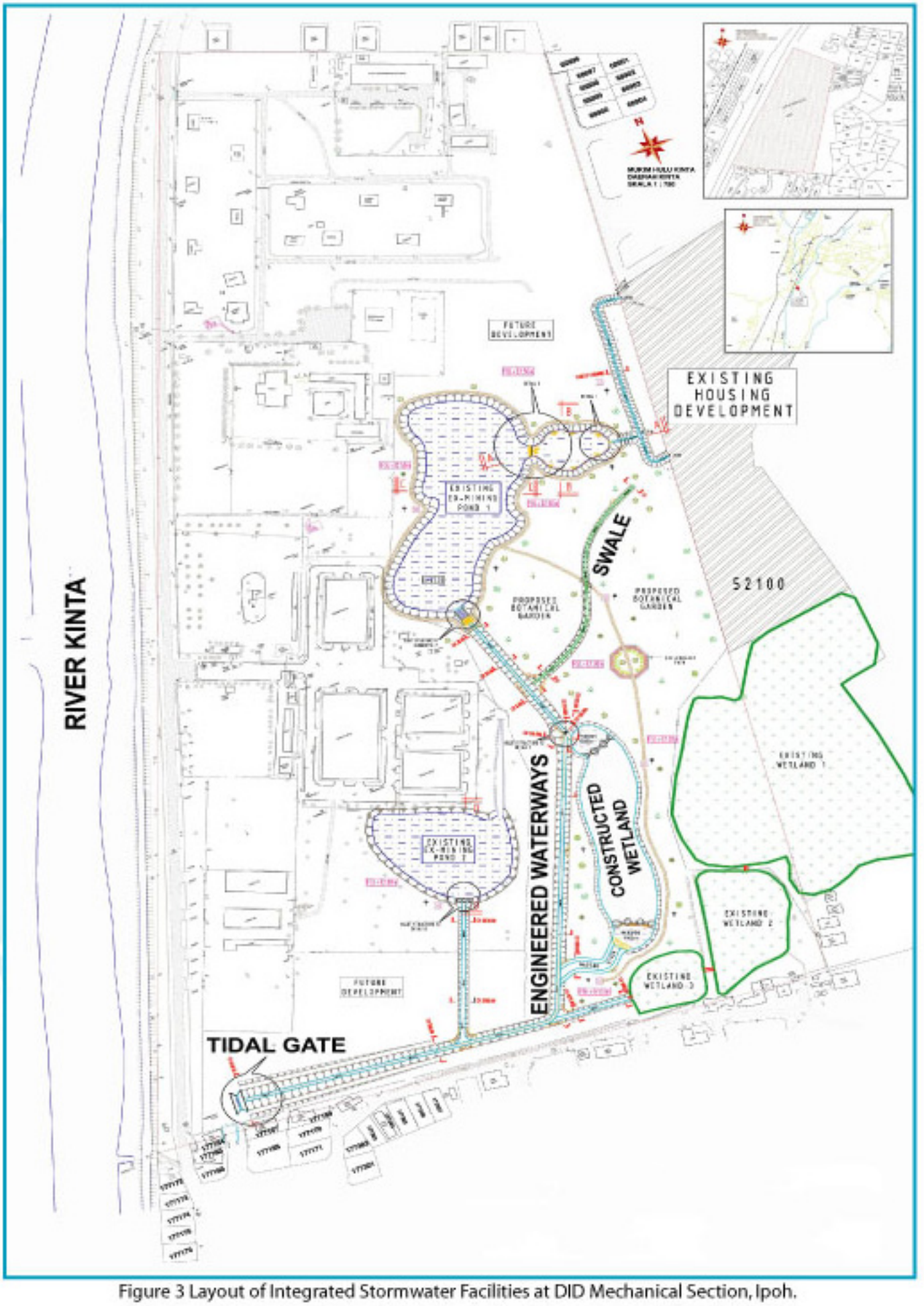



Figure 3 Layout of Integrated Stormwater Facilities at DID Mechanical Section, Ipoh.

## OBJECTIVES OF STUDY

The objectives of this Study are stated as below:

(a) To set-up an example and showcase of ex-mining pond rehabilitation and restoration as storm water facilities in Malaysia.
(b) To study the existing hydraulic and hydrologic characteristics of existing ponds and the surrounding drainage system.
(c) To evaluate the effectiveness of the proposed rehabilitation and restoration works
(d) To establish the data collection system to monitor the hydraulic, hydrology and water quality parameters in the study area.
(e) To carry out the cost benefit analysis for the proposed system.
(f) To establish the guideline for rehabilitation and restoration of ex-mining pond for storm water and recreational purposes.

## CONCEPTUAL DESIGN

The main components of the proposed integrated storm water facilities include Ex-mining pond 1 (Figure 4) designed as a regional pond to control both water quantity and quality from the study site and the surrounding areas. The conveyance system is made of an engineered waterway (Figure 5) with features those of natural rivers. Storm water runoff from the botanical garden is conveyed to the engineered waterway via swale (Figure 6).

Further treatment of storm water runoff is provided through a constructed wetland (Figure 7) connected to the Ex-Mining Pond 1 via the engineered waterway. The existing wetland will treat runoff from the nearby surrounding areas located outside of the study area. The Ex-Mining Pond 2 (Figure 8) is designed as a community pond to control both water quantity and quality from the study site only. An automatic tidal gate is provided at the downstream end before the runoff is discharged to River Kinta (Figure 9).

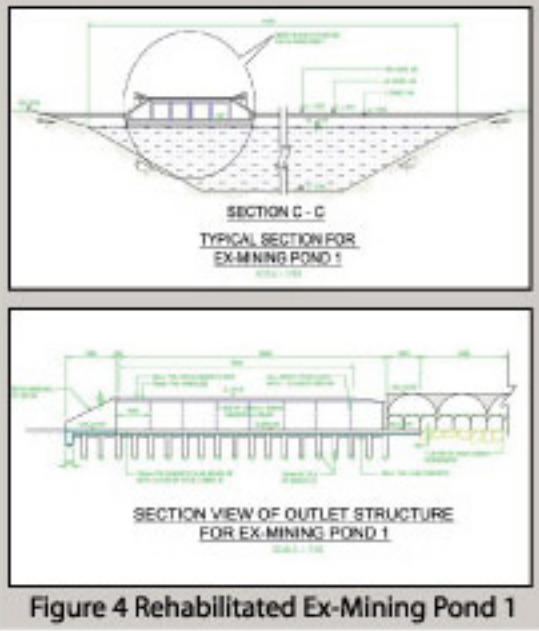



Figure 4 Rehabilitated Ex-Mining Pond 1

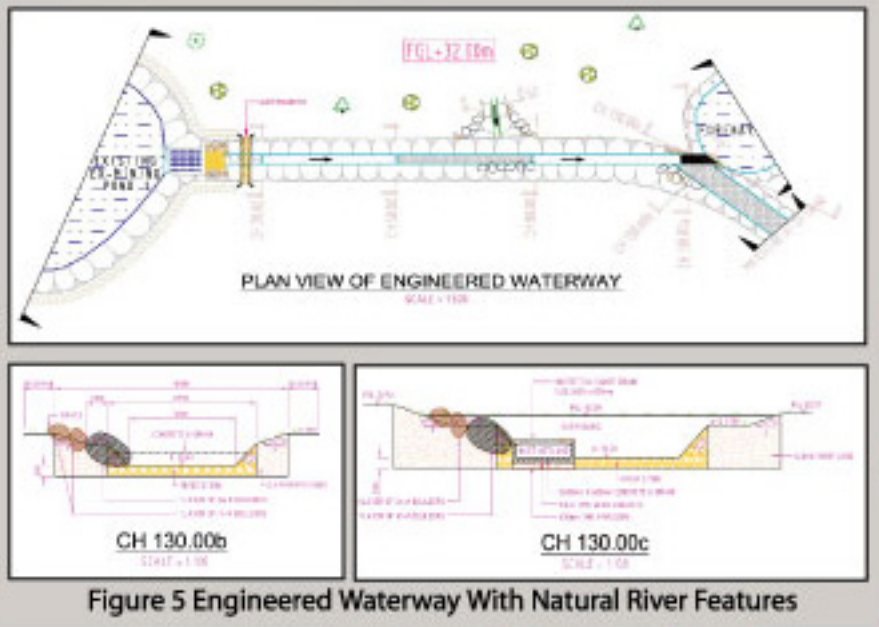
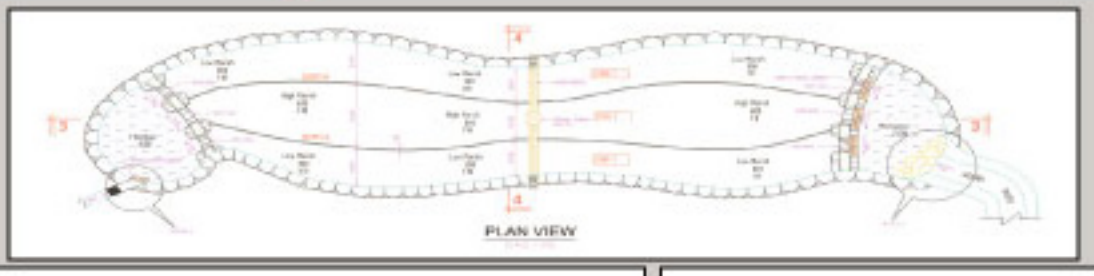
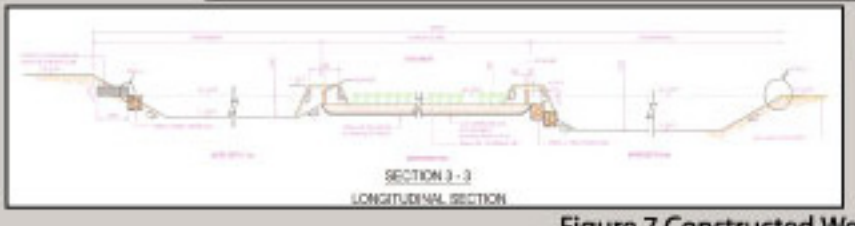



Figure 5 Engineered Waterway With Natural River Features


Figure 6 Swale

# INNOVATION



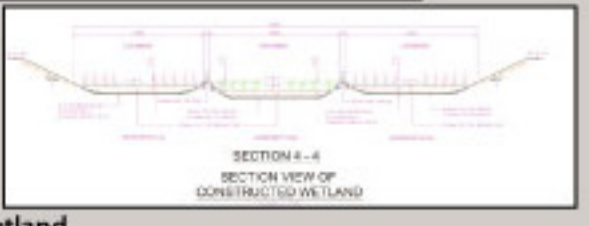
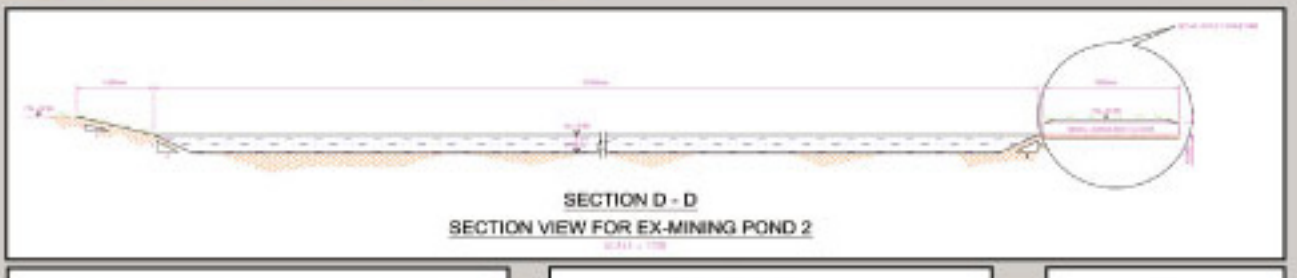




Figure 7 Constructed Wetland



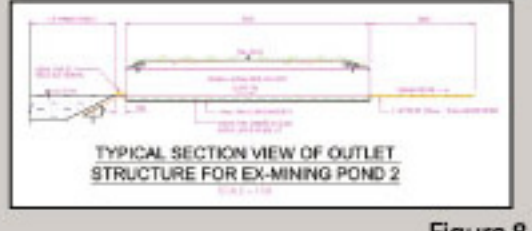






Figure 8 Rehabilitated Ex-Mining Pond 2

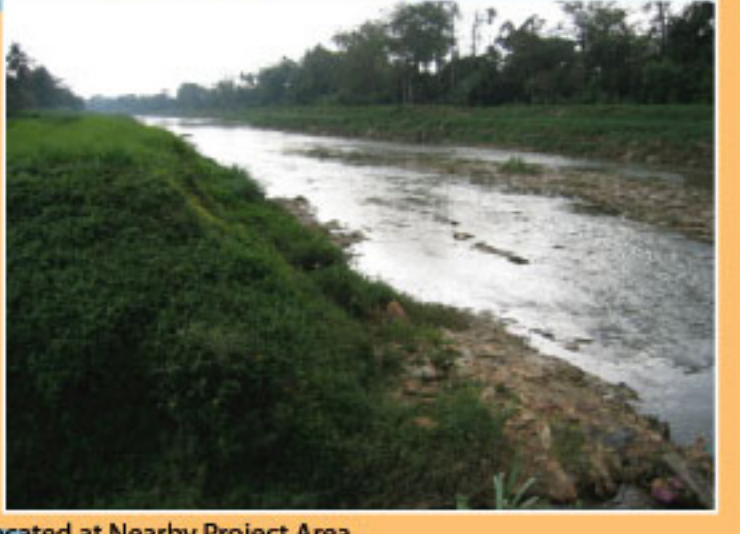


Figure 9 River Kinta Located at Nearby Project Area

## CONCLUSIONS

The design of the project is based on MSMA by providing a series of treatment train for both storm water quantity and quality control. The construction of the proposed storm water facilities will provide an excellent example of storm water management components for other locations throughout Malaysia.

## ACKNOWLEDGEMENTS

REDAC would like to thank DID Malaysia for continuing support by providing the contract research grant (JPS (PP) / SG / 06 / 05) for the study.

# VISIT TO BIOECODS™

## Department of Irrigation and Drainage, Kedah,
24th November 2005

Members of the Intergrated River Basin Management (IRBM) Committee, Kedah, visits the BIOECODS project on 24th November 2005. Briefing on the project was given followed by a technical tour.


BIOECODS Briefing

## Recreational Pond

# VISIT TO BIOECODS™

Department of Irrigation and Drainage Malaysia &
Malaysian Institute for Nuclear Technology Research
22nd December 2005

BIOECODS Briefing

DID Malaysia and MINT visited the BIOECODS project during their annual meeting at Bukit Merah Lake Town Resort. Briefing and tour of the project were the highlight of the visit.

Ecological Swale

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# BIOECODS at Taiping, Perak

## INTRODUCTION

River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia has been appointed to provide consultancy services for the drainage works as part of Civil and Structure components for the proposed "Cadangan Mendirikan Sebuah Klinik Kesihatan Taiping – 2 Tingkat (Jenis KK2) Di Atas Lot 2089, Jalan Tupai, Mukim Tupai, Daerah Larut & Matang, Perak Darul Ridzuan". In this project the Government is planning to construct a drainage system to comply with the new guidelines of Department of Irrigation and Drainage (DID), Urban Stormwater Management Manual for Malaysia (MSMA).

## PROJECT BACKGROUND

The Government of Malaysia via Public Works Department (JKR) Malaysia has planned to construct a new building for the Taiping Town Clinic and its infrastructure on the area approximately 7 acres in Larut & Matang District in Perak. This project consists of the construction of a double storey building block, chemical store, condenser block, TNB block, store and garage, security guard house, sewerage treatment plant, pavilion and car park. The soil profile for overall project area is consistent from silty sand at the first 10m depth to hard layer of silty clay. Ground water level is observed at 0.95m to 1.35m depth from original ground surface.

## PROPOSED DRAINAGE SYSTEM

The proposed drainage system which is known as Bio-Ecological Drainage System (BIOECODS) 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.

The new stormwater management approach, BIOECODS, based on set of broad and holistic principles for effective stormwater environment management:

- The establishment of a storage-oriented approach for controlling runoff quantity from development sites;
- The identification of the environmental values (or benefits uses) of particular water bodies which are to be protected;
- The establishment of objectives which will achieve required levels of flood protection and water quality enhancement;
- The establishment of water quality management strategies;
- The development and implementation of monitoring and surveillance programs to ensure that runoff quantity and water quality (or environmental) objec tives are being maintained; and
- The implementation of research programs to gain a better understanding of the behavior of aquatic systems in order to improve water quality design and management technique.

By integrating stormwater management planning with landscape and environmental planning, it will add aesthetic and recreational values to the water amenities. This site is planned to become a showpiece of the new drainage system for the Perak State and will also provide the database to support the new stormwater management manual as we still lack of data for local conditions and to evaluate the effectiveness of the stormwater runoff quantity and quality control system.

### Proposed Drainage Layout

The proposed drainage system has several runoff control facilities to regulate the runoff from the site as shown in Figure 1. The receiving waterway is made up of an upgraded covered concrete lined drains before discharging to River Batu Tugoh nearby.

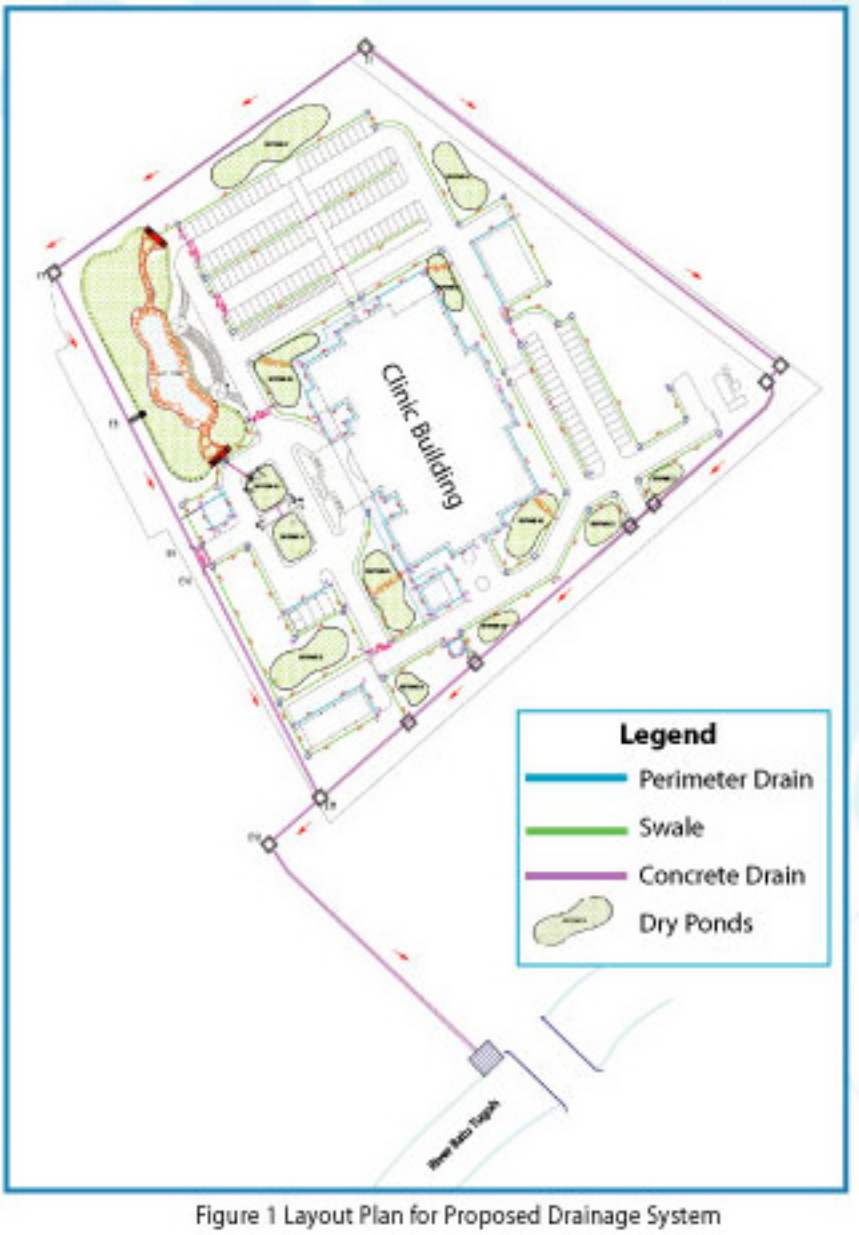


Figure 1 Layout Plan for Proposed Drainage System

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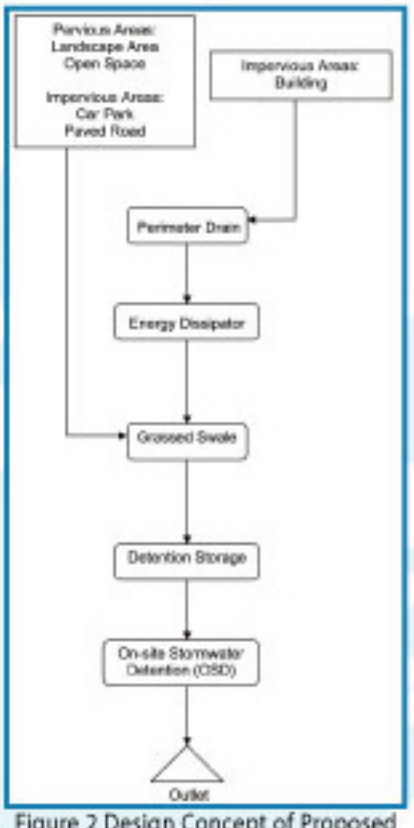


Figure 2 Design Concept of Proposed Drainage System

## DESIGN CONCEPT

The new environmental-friendly drainage system, BIOECODS, uses "control at source" principle simulating the natural hydrological cycle in urban areas by combining infiltration, detention storage, retarded flow as well as runoff treatment techniques. Among the stormwater facilities provided are grassed swale, underground detention storages and dry ponds. The design concept is given in Figure 2.

a) Grassed Swale (Figure 3)
Grassed swale is designed to cater any excess water from perimeter drain (for individual building) whilst the flow from pervious and impermeable surface will be directed to the grassed swale. The grassed swale is defined as grass earth channel combined with subsurface module which enclosed within a permeable geotextile. 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.

b) Detention Storage (Figure 4)
The excess stormwater is stored in the subsurface detention storage. The storage modules have been designed to be places at the connecting points, junction and critical point of the system. These detention storages are provided to reduce flows from the building, regulating flow velocity which causes the gravity settling of particulates and increase the infiltration process where all these mechanisms will control the quality and quantity of stormwater runoff.

c) On-site Stormwater Detention (OSD)
The excess stormwater is also stored in the dry pond constructed with a storage function. The dry pond 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. OSD is normally dry or empty when not in operation. It will be utilized for multi-purpose use to incorporate passive and active recreational areas such as public parks and open space or sporting facilities.

## SUMMARY

The proposed BIOECODS is an applicable concept that will fulfill new urban stormwater management objectives to restore each component of the hydrological cycle to its natural level. This new stormwater management approach has taken into broad consideration with the purposes:

- to provide safety for the public,
- to minimize and control nuisance flooding,
- to stabilize the landform and erosion control,
- to enhance the urban landscape, and
- to minimize the environmental impact of urban runoff on water quality.

## ACKNOWLEDGEMENT

REDAC would like to thank Public Works Department (JKR) for the opportunity to participate in this project.

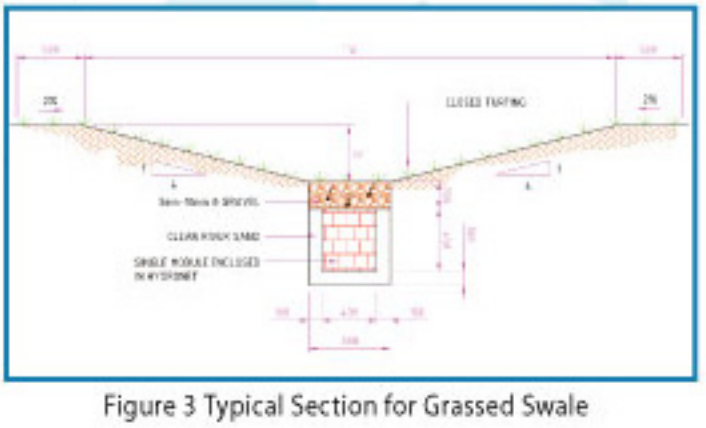

Figure 3 Typical Section for Grassed Swale

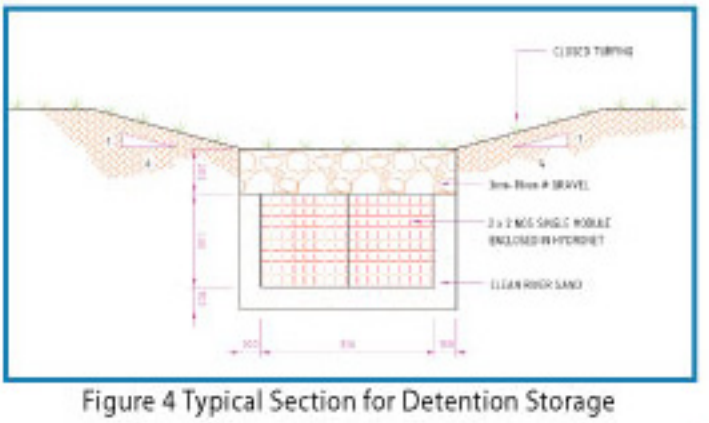

Figure 4 Typical Section for Detention Storage

# XXXI IAHR CONGRESS

## Water Engineering for the Future: Choices and Challenges

The XXXI Congress of International Association of Hydraulic Engineering and Research (IAHR) was organised from September 11th - 16th, 2005 at Seoul, Korea.

The IAHR General Lecture was given by Datuk Ir. Hj. Keizrul Abdullah, President of International Commission on Irrigation and Drainage (ICID) & Director General, Department of Irrigation and Drainage Malaysia.

Two papers on REDAC's IRPA grant research projects were presented during the congress by Mr. Chang Chun Kiat, REDAC's Science Officer & Secretary, IAHR Student Chapter - USM.


**(Datuk Ir. Hj. Keizrul at the far right)**




# CONFERENCE


Mr. Chang Chun Kiat with Dr. Chiew Yee Meng, Nanyang Technological University, Singapore (a), Prof. Pierre Julien (b) Prof. Chih Ted Yang, Colorado State University, USA and (c) Dr. Etienne Mansard, Canada, IAHR President (d).

# POSTGRADUATE

**Name** : Abdul Jalil Hassan (MSc Candidate : S-REM0001)

**Project Title** : Effect of Flood Plain on Flood Inundation Prediction For River Selangor

**Supervisors** : 1. Assoc. Prof. Dr. Aminuddin Ab. Ghani 2. Assoc. Prof. Dr. Rozi Abdullah

**Present Status** : Completed (February 2006)

## INTRODUCTION

Two common approaches to solve flood problem that has been recognized are structural and non structural measure. Structural measure such as river widening, deepening and straightening is targeting to reduce flood magnitude but at the same time might transfer the flood problem to the downstream. For non structural measures, tools such as computer model can be used to quantify the effects of human interference to the river system. Such tools already available in advanced country but the application is still new in this country. It is important to carry out thorough analysis to understand the flood behaviour before any structural measures are carried out. Therefore, before any activities are implemented within the catchment and the flood plain, river engineers are able to evaluate potential impact of flood extent and advice the implementing agencies to carry out further prevention measure to avoid the anticipating problem that might occur.

## STUDY OBJECTIVES

The main purpose of the study is to develope a complete river model using InfoWorks RS consisting of hydrological, hydraulic and ground model covering main river system and flood plain. The model will generate a flood risk map based on various return period and provide quick results on flood impact due to probable human activities within a catchment (Hassan, 2004).

## STUDY AREA

River Selangor is located at northern part of the state of Selangor. The catchment is approximately 1960km$^2$ which cover about a quarter of the state of Selangor. The main river, River Selangor starts from the west of Titiwangsa Range at elevation about 1700m between the borders of state of Pahang. It flows approximately 110km toward the southwest to the Straits of Melaka. The major tributaries which joint the river are River Kerling, River Kubu, River Rening, River Batang Kali, River Buloh and River Sembah. Figure 1 shows the main river and the subcatchments.

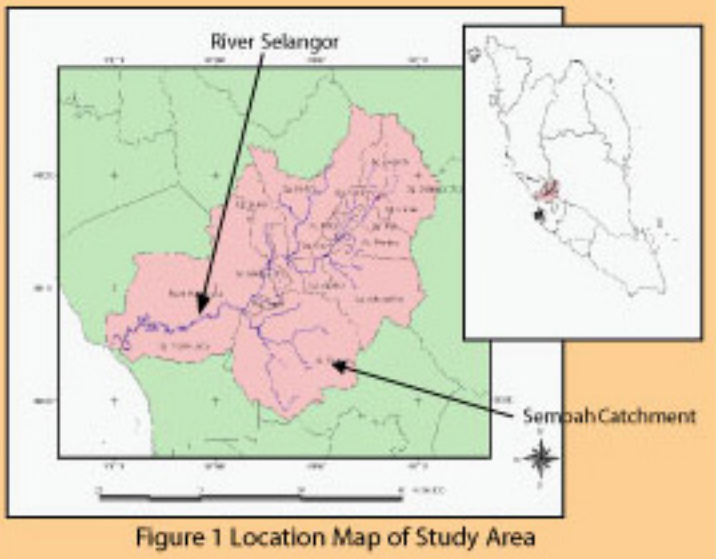


Figure 1 Location Map of Study Area

On the East of the basin is a mountainous area mainly covered with forest and plantation while the West side is generally swampy and flat with paddy as the main agricultural activities. The most recent landuse map for the catchments is shown in Figure 2.

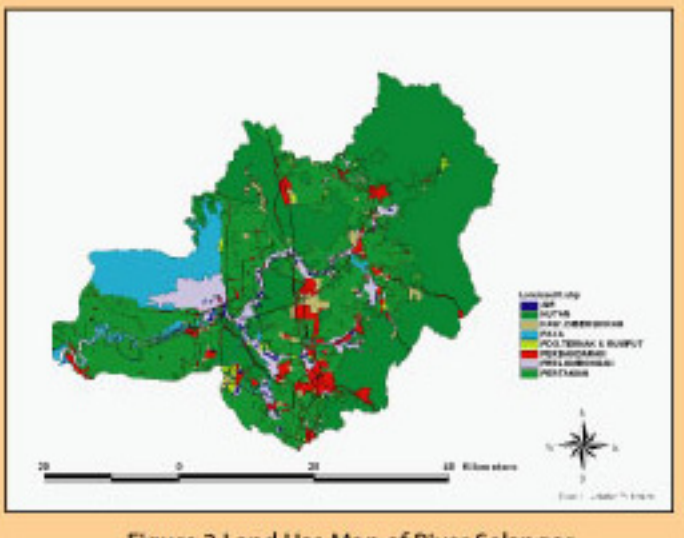

Figure 2 Land Use Map of River Selangor

River Selangor was selected for this study because of availability of river survey data together with the ground elevation of the flood plain within 500m to 2 km at each side of the river. Concurrently, due to its location, it is a potential area to be developed since the adjacent Klang Valley development is almost reaching saturation level in the near future.

## METHODOLOGY

The process to develop the river and flood plain model consists of 3 main components. The components are the hydrologic rainfall-runoff model, hydrodynamic model and 3D ground model. Flow from sub catchments to the main river are represented by rainfall runoff model based on US SCS method. These flows connect to the river at the confluence of the tributaries. The river is modeled by cross sections at 1km apart based on ground survey carried out in 1998. The model network starts from the river mouth up to about 110km upstream where a new "SPLASH" dam was constructed and completed in 2005. The river section was extended to the flood plain based on conditions below:

# RESEARCH

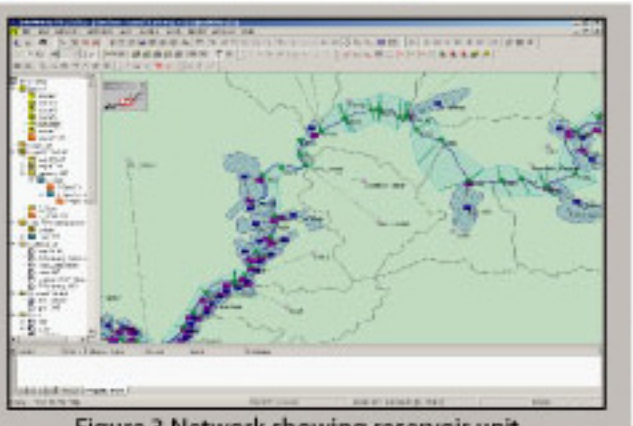

Figure 3 Network showing reservoir unit

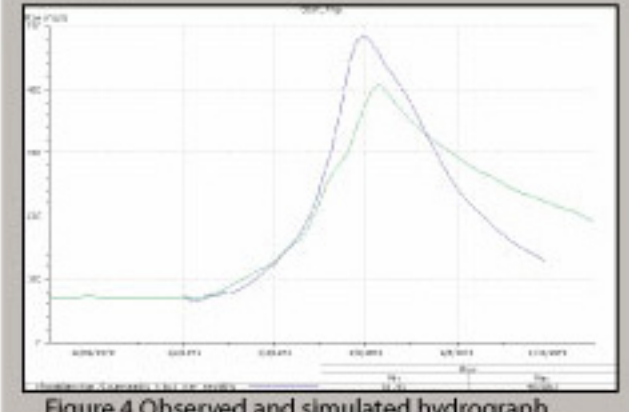

Figure 4 Observed and simulated hydrograph for 1971 flood at Rantau Panjang

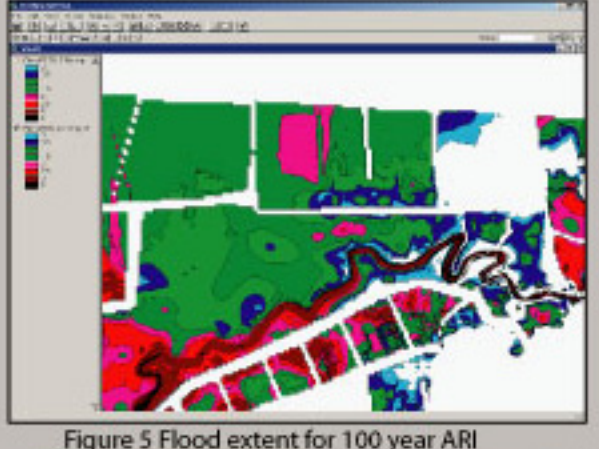

Figure 5 Flood extent for 100 year ARI

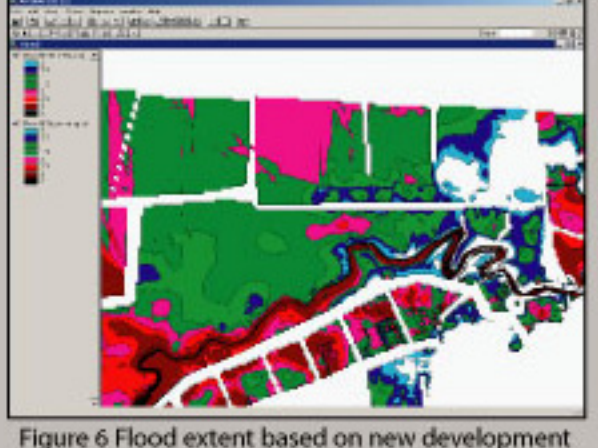

Figure 6 Flood extent based on new development in Sembah Catchment

- Normal extent up to expected flood level if the ground has smooth / gradual change of elevation
- Use of pond / reservoir where the ground is interrupted by bund or road
- Pond / reservoirs are connected to river section or other reservoir using spill unit where spill elevation is based on the bund or road level.

The hydrodynamic model using InfoWorks RS is shown in Figure 3 while Figure 4 shows the results of calibration for 1971 flood.

## RESULTS

The flood maps for 100 ARI are shown in Figure 5 and 6. Flood extent produced from InfoWorks RS was exported to Arc View shape file which can be used for other overlay process in GIS. The flood maps contain the depth contour along the flooded plain. Total flooded area within ground model is approximately 3140 hectares.

Comparing to the existing condition and land use change in Sembah Catchment, some of the impacts are observed as below:

- Flood peak increases about 15%
- Flood reaches the peak about 12 hours earlier than the existing condition.
- Water level in the flood plain downstream of the Sg. Sembah confluence increases about 0.5m and gradually reduces to 0.2m in about 40km distance.
- Flood extent within the ground model increases from 3140 hectares to 3203 hectares. The small increment is due to the edge are controlled by bund and roads.

These results are based on one storm pattern with an assumption that the storm was distributed evenly in the catchment at the same time. Further analysis can be done by changing the phase of the storm within the basin.

## CONCLUSIONS

The study has shown that automatic flood map delineation can be done with the combination of hydrological, hydraulic and ground model. Besides good hydraulic model, the quality of the flood extent very much depends on the quality of the ground model.

Generation of flood risk map for various ARI can be done for the whole catchment by changing some important parameters within the model. For the case of River Selangor which covers a distance of 110 km and total catchment area of 1960 $km^2$, the ground model was developed at a very fine 10m grid which causes the file size to be about 700Mbyte. The simulation process for 120hrs duration took about 40-60 minutes to complete on Pentium IV. The processing time will definitely can be reduced with the development of new high speed computer in the future.

With this development, flood risk map can be a quick decision support system tool to study the impact of either plan or unplanned human activities at catchment area of a river system.

## REFERENCE

Hassan, A.J. (2004). Floodplain analysis and development of flood risk map for River Selangor Basin, 1st International Conference on Managing Rivers in the 21st century: Issues and Challenge, 21st - 23rd September 2004, Penang, Malaysia, pp. 465 - 472.

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USWM - 3

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