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PROFILE



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REDAC PROFILE

RIVER ENGINEERING AND URBAN
DRAINAGE RESEARCH CENTRE



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1.0 INTRODUCTION

The University Senate formed a Study Committee in their 145th meeting on April 22, 2000 under Clause 22[b], Constitution of USM to consider the proposal to form River Engineering and Urban Drainage Research Centre (REDAC). The committee met on June 9, 2000 and was chaired by Yang Berbahagia Dato' Professor Jamjan Rajikan representing Yang Berbahagia Dato' Professor Vice Chancellor. The committee agreed and fully supported the establishment of REDAC to fulfill the need of the present and future research in River Engineering and Urban Drainage.

In the 146th Senate Meeting on June 22, 2000, the resolution to form REDAC was presented and agreed. The University Board of Directors (LPU)'s meeting on July 26, 2000 affirmed the establishment of REDAC. Subsequently a report on the proposal to form REDAC was forwarded to the Department of Higher Education, Ministry of Education for evaluation. On April 17, 2001, the Ministry of Education confirmed the resolution by the Higher Education Committee dated May 13, 2001 for the establishment of REDAC commencing on 2001/2002 Academic Year. Subsequently, Professor Nor Azazi Zakaria and Professor Aminuddin Ab. Ghani were appointed as the Director and Deputy Director of REDAC respectively.

REDAC is the first research centre at the Engineering Campus USM and was established on May 31, 2001. REDAC has been active in research and consultancy projects in River Engineering and Urban Drainage since 1997. The sponsors of the projects include the Ministry of Science, Technology and Innovation (MOSTI), Ministry of Higher Education (MOHE), Ministry of Natural Resources and Environment (NRE), Ministry of Agriculture and Agro-Based Industry (MOA), Department of Irrigation and Drainage (JPS), Prime Minister's Economic Planning Unit (EPU), Seberang Perai Municipal Council (MPSP) and Public Works Department (JKR). REDAC has received more than RM 20 million for the last ten years to conduct research and innovation.



REDAC has developed an ecologically sustainable solution to the flooding and pollution problems using the “control at source” approach known as Bio-Ecological Drainage Systems (BIOECODS) constructed at USM Engineering Campus, Penang. BIOECODS emphasizes the importance of a holistic approach to environmental engineering and landscape architecture making it unique and innovative in the field of stormwater management and urban development. Presently, the pilot project is an example for the development of new urban areas by implementing several components of BIOECODS at once that can meet the requirements of Stormwater Management Manual for Malaysia (MSMA) to manage and control stormwater runoff quantitatively and qualitatively at its source. The application of BIOECODS is an innovation to solve three major problems commonly encountered in Malaysia namely flash floods, river pollution and water scarcity during dry periods. It is hopeful that new developments in Malaysia will implement BIOECODS to help preserve the natural characteristics of the existing rivers in line with the national “Love Our Rivers (*Sungaiku Hidupku*)” campaign. The national launching of the BIOECODS was performed by His Excellency the Governor of Penang, Tun Dato’ Seri (Dr) Haji Abdul Rahman Abbas, on February 4, 2003 representing the successful implementation of the MSMA.

Recent studies include River Sand Mining Capacity in Malaysia, Design Options of the Flood Mitigation Plan of River Muda, River Inventory and Monitoring Program (RIMP), Erosion and Sediment Control in Malaysia, Stormwater Management and Drainage Masterplan Study (Tanjung Malim, Kulim Hi-Tech Industrial Park, Tanah Merah). REDAC is also involved in the preparation of Urban Stormwater Management Planning and Design Standard for Malaysia, and Second Edition Urban Stormwater Management Manual for Malaysia. REDAC has received national and international visitors and also won several awards for the ongoing research.

REDAC offers research studies in specialized areas of Urban Drainage Management, River Management, Hydro Informatics and Environmental Hydraulics Management. Further information on research activities of REDAC can be obtained from the following website: <http://redac.eng.usm.my>.



2.0 RESEARCH NICHE AREAS

Research objectives of REDAC:

1. To accelerate the realization of urban drainage metamorphosis in order to transform the quality of life in urban areas.
2. To make a holistic research and to develop new technology in River Engineering and Urban Drainage.
3. To become a Centre of Excellence in River Engineering and Urban Drainage for engineers and scientists from Malaysia and South East Asia region.
4. To promote research network and international cooperation in River Engineering and Urban Drainage Research.

Niche Areas of REDAC:

1. River Management
2. Urban Drainage Management
3. Hydro Informatics
4. Environmental Hydraulics Management





ORGANISATION

Director Prof. Nor Azazi Zakaria (PhD, MSc, BSc, Dip.)



1989	Graduate Member, Board of Engineers (BEM), Malaysia
1996	Malaysian National Committee on Irrigation and Drainage (MANCID)
2003 -	Executive Committee, MANCID
2004	Member, Malaysian Water Partnership (MyWP)
2007 -2009	Editorial Advisory Panel (EA), Proceeding of Institution of Civil Engineers (ICE), Water Management
2009	Member, International Association for Hydro-Environment Engineering and Research (IAHR)
2010 -	Executive Committee, Malaysian Stormwater Organization (MSO)

Deputy Director Prof. Aminuddin Ab. Ghani (PhD, MSc, BSc)



1995	Graduate Member, Board of Engineers (BEM), Malaysia
1998	Graduate Member, Institution of Engineers (IEM), Malaysia
1996	Malaysian National Committee on Irrigation and Drainage (MANCID)
1998 -2002	Executive Committee, MANCID
1991	Member, International Association for Hydro-Environment Engineering and Research (IAHR)
1998	Member, International Association of Hydrological Sciences (IAHS)
2008	Expert, Directory of Oceanography and Marine Science Experts in Malaysia (MyNODC)
2010	Member, Malaysian Stormwater Organization (MSO)
2009 -2012	Executive Committee, Asia Pacific Division (APD), IAHR
2003 -2011	Advisory Board, International Journal of River Basin Management, IAHR
1996 -2012	Committee Member, Sewer Systems and Processes Working Group (SS&PWG), IWA/IAHR Joint Committee on Urban Drainage
2009 -	Associate Editor, Malaysian Journal of Civil Engineering
2011 -	Editorial Board, International Journal of River Basin Management, IAHR

Dr. Hazi Md Azamathulla (PhD, ME, BTech)



1998	Life Member, Indian Society for Hydraulics (ISH)
2006	Associate Member in Institution of Engineers (India)
2007	Member of International Flood Network (IFNet), Japan
2008	Member of International Association of Hydrological Sciences (IAHS), UK
2009	Member, American Society of Civil Engineers (ASCE)
2009	Member of International Association of Engineers (IAENG)
2009	Member, World Academy of Science and Engineering Technology (WASET)
2009	Member, Malaysian National Committee on Irrigation and Drainage (MANCID)
2009 -	Editorial Member, Dam Engineering Journal
2009 -	Editorial Member, International Water Power and Dam Construction, IWP & DC, UK
2010 -	Associate Editor, Journal of Pipeline Systems Engineering and Practice, ASCE
2011 -	Associate Editor, Water Science & Technology, IWA
2011 -	Associate Editor, Water Supply and Water Practice and Technology, IWA

Engr. Zorkeflee Abu Hasan (MSc, BSc)



- 1980 Graduate Member, Board of Engineers, Malaysia
- 2008 Member, Malaysian National Committee on Irrigation and Drainage (MANCID)
- 2009 Certified Professional in Erosion and Sediment Control (CPESC), USA

Engr. Mohd Fazly Yusof (BEng)



- 2001 Graduate Member, Board of Engineers, Malaysia
- 2010 Member, Malaysian Stormwater Organization (MSO)
- 2011 Member, Malaysian National Committee on Irrigation and Drainage (MANCID)
- 2011 Member, Malaysian Water Partnership (MyWP)

Engr. Chang Chun Kiat (MSc, BEng)



- 2002 Graduate Member, Board of Engineers, Malaysia
- 2003 Graduate Member, The Institution of Engineers, Malaysia
- 2009 Certified Professional in Erosion and Sediment Control (CPESC), USA
- 2009 Member, Malaysian Water Partnership (MyWP)
- 2010 Member, International Association of Hydrological Sciences (IAHS)
- 2010 Member, Malaysian Stormwater Organization (MSO)
- 2011 Member, Malaysian National Committee on Irrigation and Drainage (MANCID)

Engr. Leow Cheng Siang (BEng)



- 2008 Graduate Member, Board of Engineers, Malaysia
- 2008 Graduate Member, The Institution of Engineers, Malaysia
- 2009 Certified Professional in Erosion and Sediment Control (CPESC), USA
- 2010 Member, Malaysian Stormwater Organization (MSO)
- 2011 Member, Malaysian National Committee on Irrigation and Drainage (MANCID)
- 2011 Member, International Association of Hydrological Sciences (IAHS)

Muhamad Nurfasya Alias (BEng, Dip., Cert.)



- 2010 Member, Malaysian Stormwater Organization (MSO)
- 2011 Member, Malaysian National Committee on Irrigation and Drainage (MANCID)

Muhammad Zaki Mohd Kasim (BEng)



- 2010 Member, Malaysian Stormwater Organization (MSO)
- 2011 Member, Malaysian National Committee on Irrigation and Drainage (MANCID)

Khairul Rahmah Ayub (MSc., BSc)



- 2005 Member, Environmental Management and Research Association of Malaysia (ENSEARCH)
- 2010 Member, Malaysian Stormwater Organization (MSO)
- 2011 Member, Malaysian National Committee on Irrigation and Drainage (MANCID)

Syafiq Shaharuddin (BSc)



- 2011 Member, Malaysian National Committee on Irrigation and Drainage (MANCID)



4.0



**RESEARCH AND
INNOVATION**



4.1 INTERNAL GRANTS

Title: A Study on Erosion and Sedimentation in Rivers through Sediment Transport Process

Type: USM Short Term Grant

Year: 1994 - 1996

Amount of Grant: RM 20,000.00

Title: Soil Improvement Method using Reinforced Earth Technique

Type: USM Short Term Grant

Year: 1995 - 1997

Amount of Grant: RM 15,000.00

Title: Field Data Collection on Sedimentation in Storm Drains

Type: USM Short Term Grant

Year: 1996 - 1998

Amount of Grant: RM 20,000.00





Title: Stormwater Pollutant Removal using Swales

Type: USM Short Term Grant

Year: 2005 - 2007

Amount of Grant: RM 20,000.00

Executive Summary :

Rapid urbanization and lack of proper water resources management have led to various water related issues in Malaysia. Areas with heavy and active development are prone to flash flood, water supply crisis and water pollution. Various reports on flash floods in Kuala Lumpur and Shah Alam by the mass media confirmed the severity of water management issue in urban areas. As a result of such events, millions of Ringgit were spent to rectify flood damages and to execute emergency reliefs. Even more millions were lost due to property damages, economic and social damages. It is obvious that population growth and the subsequent urbanization have adverse impact on the natural hydrological cycle. Therefore, Malaysia and other countries alike, should adopt a holistic and integrated approach in tackling the complex issue of hydrological change due to urbanization. The implementation of Integrated Flood Management (IFM) is an effective way to tackle flash flood, water scarcity and water source pollution issues. In conventional stormwater management approach, stormwater is conveyed to the discharge point as fast as possible. A new approach, which is the Sustainable Urban Drainage Systems (SUDS) has been developed due to the shortcoming of conventional system. This new approach combines water quantity control, water quality control, and public amenity as the three main components of stormwater management. Generally, SUDS adopts a control-at-source concept in treating stormwater. In terms of water quality control, a research in Universiti Sains Malaysia engineering campus found that the Bio-ecological Drainage System (BIOECODS), which is the pilot project to exhibit SUDS application in Malaysia, was able to overcome the issues discussed above. The findings of the research showed that the final discharge from the system was well-treated and is categorized as Class IIB according to the Interim National Water Quality Standard.

Title: Modification of Einstein's Bed Load Transport Formula for Rivers in Malaysia
(Case Study of Kulim River, Kedah)

Type: USM Short Term Grant

Year: 2006 - 2008

Amount of Grant: RM 20,000.00

Executive Summary :

A total of 346 sets of bed load data obtained from the Kinta River, Pari, Kerayong River and Langat River were analyzed using four common bed load equations (Einstein, Einstein-Brown, Meyer-Peter-Müller and Shields). These assessments, based on the median sediment size (d_{50}), showed that the existing equations were unable to predict the measured bed load accurately. All existing equations over-predicted the measured values, and none of the equations gave satisfactory performance when tested on local river data. Therefore, this study had developed a Modified-Einstein Equation which employs local sediment transport data to yield a better equation that can accurately predict bed load transport in Malaysian rivers. Using the recommended Modified-Einstein Equation, the computed bed load transport rates were in much closer agreement with the actual measured bed load. The results were confirmed using the newly measured data at Kulim River. This study also applied a new soft computing technique, i.e. an adaptive neuro fuzzy inference system (ANFIS) as an alternative to more conventional bed load predicting equations for bed load prediction. The results showed that the recommended network was able to predict bed load more accurately when compared to a regression based equation for moderate-size and sand-bed streams in Malaysia.



Title: Flow Attenuation of BIOECODS Ecological Ponds

Type: USM Short Term Grant

Year: 2006 - 2008

Amount of Grant: RM 20,000.00

Executive Summary :

The launching of the new Urban Storm Water Management Manual for Malaysia (MSMA) emphasizes on the implementation of the Best Management Practices (BMPs) that utilize detention ponds, swales, wetlands, sand filter dry pond, etc. Since January 1, 2001, new development in Malaysia must comply with MSMA to control stormwater runoff in terms of quantity and quality to achieve zero development impact contribution to overcome the problems of flooding and stormwater runoff pollution. Universiti Sains Malaysia in collaboration with Department of Irrigation and Drainage Malaysia, have implemented Bio-Ecological Drainage System (BIOECODS) as a showpiece of the sustainable urban drainage in Malaysia. BIOECODS represents application of swales, sub-surface modules, dry pond, wetpond, detention pond, constructed wetlands and wading river. The ecological pond, which is placed at the downstream end of BIOECODS, is a community facility that includes a wet pond, and a detention pond as a facility to control the stormwater quantity, a constructed wetlands as a water treatment device, a wading river connecting the wetlands and a recreational pond containing the treated water before final discharge to Sungai Kerian. The ecological pond system is strategically placed at the downstream end of the BIOECODS to optimize and effectively attenuate and treat stormwater runoff generated from the built areas of the USM Engineering Campus. This research had verified the effectiveness of pond facilities as one of the BIOECODS component in reducing the peak flow and discharge of stormwater in a new development area before entering river system as required in the MSMA. The study covered site monitoring and records analyses within the study period. The ecological pond system was gauged with hydrological stations that record velocity and water level at 5 critical points, including inflow and outflow of each components.





Title: Stormwater Pollutant Removal Using Retention Pond (Wetpond, Detention Pond and Wetlands)

Type: USM Short Term Grant

Year: 2006 - 2008

Amount of Grant: RM 15,000.00

Executive Summary :

Bio-Ecological Drainage System (BIOECODS), the first Malaysian pilot project for SUDS, was developed at Engineering Campus, Universiti Sains Malaysia which consists of quantity control, quality control and amenity in a holistic control-at-source approach. The BIOECODS is appropriate to solve three commonly water related problems namely, flash flood, water shortage and water pollution. In this research, only ecological ponds (wetpond, detention pond and wetlands) of the BIOECODS system were studied. It was found that ecological ponds were capable of treating stormwater runoff from the study area. Percentages of pollutants removal for various water quality parameters are in the range of 7 % to 94 % for the studied rainfall events. The findings of the research showed that the final discharge from the system is well-treated and is categorized as Class IIB according to the National Water Quality Standard, Malaysia. A further study on water balance for BIOECODS' constructed wetland shows that it was capable to supply water for the planted wetlands macrophytes.

Title: Prediction of Scour around Hydraulic Structures using ANN, ANFIS and Genetic Programming (GP)

Type: USM Short Term Grant

Year: 2007 - 2009

Amount of Grant: RM 30,000.00

Executive Summary :

When a structure (spillway or bridge pier) is placed in a hydraulic/marine environment, the presence of the structure will change the flow pattern in its immediate neighbourhood and cause an increase in the local sediment transport capacity and thus lead to scour. Scour can induce failure of hydraulic and marine structures. Costs involved for repair of the failed parts of river/coastal structures are huge and induce unnecessary burden on the government. This study investigated the application of soft computing techniques in prediction of complex scour phenomenon around several hydraulic structures. These structures included, Bridge Pier Scour (ANN, GP, Regression Model), Pile Scour (LGP, ANFIS), Ski-jump Bucket Spillway Scour (GP), Scour below Flip Bucket Spillway (Regression Model, GP), and Scour on spillway (ANN). The data used in this study were contributed by overseas researchers, obtained from physical simulations on variety of hydraulic and structural conditions. 75% of the datasets were used for training the soft computing models, while 25% is used for testing. Whenever applicable, the soft computing techniques were compared to conventional regression models. All the investigations, soft computing models performed more superiorly over conventional regression model. The study concluded that soft computing techniques are very suitable to be applied in engineering applications.



Title: The Use of MSMA for Integrated Urban Drainage Management: Case Study in Ipoh and Melaka

Type: USM Short Term Grant

Year: 2007 - 2010

Amount of Grant: RM 40,000.00

Executive Summary :

Floods are the most damaging natural disasters that have been haunting many parts of Malaysia. Frequent occurrences of flash flood in urban areas result in an average loss of RM 100 million a year. With the present conventional drainage system, new development means new and bigger monsoon concrete drains are required at the downstream areas. Similarly the receiving river at the downstream end will need new flood mitigation works normally involving straightening, widening and deepening of river channel that destroy the riverine and aquatic ecosystems. It is clear that study on sustainable strategy for urban stormwater management and flood prevention is needed. Therefore, two urban stormwater management projects have been selected to study the use of Urban Stormwater Management Manual for Malaysia (MSMA) concepts proposed by the Department of Irrigation and Drainage (DID) Malaysia for Integrated Urban Drainage Management. These projects are: (1) Rekabentuk terperinci sistem saliran Maktab Perguruan Perempuan Melayu Melaka – Taman Peringggit Jaya and (2) Rehabilitation of ex-mining pond and existing wetlands for integrated stormwater facilities, Ipoh.

This study proved the effectiveness and potential of MSMA concepts as a sustainable strategy for integrated urban drainage management, i.e. improving water quality, reducing peak and volume of stormwater runoff at source. The outcome also provided a good example for integrated urban drainage management in future. This management concept is a cost effective method to the country by eliminating the need to upgrade the existing conventional drainage system by controlling the stormwater at source. The new system with environmental friendly components will minimise urban flash flood and remain in harmony with nature. Our river systems will also be saved from further destruction due to conventional flood mitigation projects.

Title: Integrated Urban Drainage Management (INUDRAM)

Type: USM Research University Grant (Golden Goose Project)

Year: 2007 - 2010

Amount of Grant: RM 470,000.00

Executive Summary :

Frequent occurrences of flash flood in urban areas result in an average loss of RM 100 million a year. Department of Irrigation and Drainage Malaysia (DID) estimates that RM 10 billion is required to upgrade the conventional drainage system made up of concrete channels and channelized rivers to overcome the flash flood enigma. Conventional drainage has also contributed to water quality degradation as it does not provide water quality treatment for stormwater runoff. With this rapid disposal system in-place, precious freshwater is drained into the sea directly, and this reduces the source of water supply in natural catchment. "Integrated Urban Drainage Management (INUDRAM)" emphasized on environmentally friendly products that will create urban areas free of flash flood, water pollution, and water scarcity and remain in harmony with nature. These issues were tackled by three research niche areas (RNA) proposed under the INUDRAM research project. The first niche area was to tackle flooding issue, and thus REDAC developed flood risk map for urbanised area by using the Sungai Muda as case study. Flood risk map was produced for the river incorporated in friendly GUI for easy retrieve of risk level in any given location.

For water quality problem, the previous research on gross pollutant trap (GPT) was continued. New modifications were made to the initial design. The new GPT was vigorously tested in laboratory scale to study the hydraulic performance and gross pollutant and sediment removal rate corresponding to various flow conditions. The GPT was in process of application for patent, and would potentially be servicing urban drainage in the future to help improve water quality of the nation. The final research niche area involved the development of subsurface geo-synthetic modular. First the modulares available on the market were tested in laboratory to obtain their characteristics. Then a prototype of a new modular with desired hydraulic properties was proposed. The new modular was designed to be more efficient in water conveyance. The new modular has the potential to be used as subsurface conveyance and storage, promoting rainwater harvesting or stormwater reuse, and indirectly creating a new alternative source of freshwater for the community.

New industries will be created to produce the products for INUDRAM enhancing our nation's aim of becoming a high-income nation by 2020. The potential products of the research project will provide cost saving to the country by eliminating the need to upgrade the existing conventional drainage system by controlling the stormwater at source, and having alternative water source for non-potable use.



Title: Integrated River Basin Management: Application of GIS-Assisted Modelling for Bukit Merah Dam Operation

Type: USM Short Term Grant

Year: 2008 - 2010

Amount of Grant: RM 35,000.00

Executive Summary :

Bukit Merah Dam is located in Kerian District, Perak, where its catchment is mostly located in the Larut, Matang and Selama District, Perak. Although the dam/reservoir was originally constructed to supply water for Kerian Irrigation Scheme, it currently is the main potable water source for Kerian District. Land use of the reservoir catchment is predominantly rural, agricultural based activities, and forested areas. Normally, any reservoir will face water quantity and quality problems. This study focused on the application of mathematical models to estimate the water quantity (flood hydrographs) and sediment yield (water quantity and storage problems) contributed by the catchment area to the dam reservoir using HEC-HMS and SWAT respectively. Geographic Information System (GIS) techniques were utilized for both modellings. This exercise was conducted as an attempt to bridge the gap between the technical and scientific facts and decision making process to ensure sustainable management of the reservoir and dam. Each model underwent the calibration and validation processes. Simulations for proposed 2015 land use and 20% increase of Curve Number (CN) values throughout the study area scenarios were conducted using the calibrated parameters. Results from the simulations using proposed 2015 land use showed an increase of peak flow by 4.7% and sediment yield by 54.86% at Pondok Tanjung. Whereas, results of simulation using the 20% increase of CN values showed an increase of peak flow by 20.48% and sediment yield by 80.88%. The results indicated that the proposed land use for year 2015 was suitable in term of flow but not for the sediment yield. Since more than 35% of the catchment areas are alienated lands, management of the catchment area requires coordinated effort to ensure the sustainability of the water resources and longevity of Bukit Merah Reservoir. This can be done by applying the Integrated River Basin Management concept. This study approach can be adopted to assist decision making. Establishment of Decision Support System can definitely enhance the Bukit Merah Dam operation.





Title: Digital Flood Mapping – Case Study of 2007 Sungai Pahang Flood

Type: USM Research University Grant

Year: 2009 - 2011

Amount of Grant: RM 100,000.00

Executive Summary :

Several major floods have been experienced in Malaysia for the last few decades. Flood occurrences seem to be getting more frequent in recent years, especially in some cities like Kuala Lumpur, Penang and Kuching where rapid urbanisation is taking place. After several major floods struck the country causing great lives and property losses since the 1960s, the government has taken several positive steps and seriously planning to envisage flood mitigation projects in its national plans. This intention was translated substantially by the establishment of the Natural Disaster Relief Committee in 1972 and the Permanent Flood Control Commission in December 21, 1971 to study the short-term measures for flood prevention and long-term measures for flood mitigation. In this study, effort was put into developing a digital flood inundation map for the 2007 flood along Sungai Pahang by gathering hydraulic and hydrologic data. Digital Elevation Model from public domain source was enhanced and corrected with accurate elevation sampling (using DGPS) along the river. The DEM was further verified using another set of site elevation data. Finally, flood profile was created in GIS using available flood records at four hydrological stations. The produced flood inundation map was validated with published flood inundation map by DID, digitised from satellite images. The produce flood inundation map allow a proper evaluation on the impact of future flood events and facilitate implementing agencies on decision making and planning of further preventative measures to avoid or minimise flood impacts.



Title: Soft Computing Technique to Predict Total Material Load for Sand Bed-River in Malaysia

Type: USM Research University Grant

Year: 2009 - 2011

Amount of Grant: RM 120,000.00

Executive Summary :

Sediment transport process in rivers is a complex phenomenon. The prediction of river sediment load constitutes an important issue in river engineering. The sediment can aggrade channel beds with excess sand and gravel for tens to hundreds of kilometres downstream. Such aggradations promotes the lateral migration of channels and may cause serious flooding during rainstorms, due to the loss of channel capacity necessary to convey floodwaters. Conventional approaches are normally able to make estimations within about one order of magnitude of the actual measurements. To overcome the complexity and uncertainty associated with total bed material load estimation, this research investigated the suitability of soft computing techniques in solving this engineering problem. Soft computing techniques namely, artificial neural network (ANN), Support vector machine (SVM) and Gene- Expression Programming (GEP) were tested using Malaysian sediment load data collected in previous studies. Among the three, GEP was found to yield the best prediction performance. GEP was employed without any restriction to an extensive database compiled from measurements in the Muda, Langat, and Kurau rivers. A total of 364 bed load datasets from the three rivers were used for this study. The GEP model was able to successfully predict total load transport in a great variety of fluvial environments, including both sand and gravel rivers. Also, the GEP estimation of mean total load was in almost perfect agreement with the measured mean total load. ($R^2 = 0.97$ MSE = 0.057). This study demonstrated a successful application of the GEP modelling to total bed material load estimation.

Title: Application of Recharge Well System For Urban Stormwater Management

Type: USM Research University Grant

Year: On going

Amount of Grant: RM 230,000.00

Executive Summary :

Batu Pahat District, especially at Parit Raja, is experiencing rapid growth since the establishment of Universiti Tun Hussein Onn Malaysia (UTHM). The existing municipal water supply is not able to fulfill the consumption requirement in terms of quantity and quality. Besides that, flood is occurring frequently in the area during rainy season. Research on soil permeability at Parit Raja found that most of the top soil layer in this area is occupied by clay, with very low infiltration rate. As stormwater runoff is not able to infiltrate, there is very little of recharge from surface water to sub soil system or aquifer. To make matters worse, most areas in Batu Pahat is flat, around 0.5 m to 1.0 m above mean sea level. This topography condition has been unfavourable for the river to discharge stormwater effectively to the sea, and therefore the area is facing flood problems every year due to tidal and back water effects. In order to solve the problems mentioned above, an integrated stormwater management strategy is required to control the stormwater at source. In this regards, recharge well system was introduced as a better alternative to pond structures in the study site. Presently, recharge well system is very new and untried in Malaysia. Therefore, this research set out to provide more information on using recharge well system for stormwater management. In order to achieve this, a recharge well was constructed and currently being monitored in UTHM compound. The recharge volume and water quality are being closely monitored to gauge the performance of the recharge well in diverting runoff to recharge groundwater. This study will provide quantitative proof of the feasibility of the system in recharging groundwater and alleviating flood.



Title: Water Quality Modelling for Intergrated River Basin Management in Sungai Raja, Kedah

Type: USM Research University Grant

Year: On going

Amount of Grant: RM 170,000.00

Executive Summary :

Integrated River Basin Management (IRBM) is an approach to water resources management that takes into account all factors linked to the water resources, including social and economic activities. Its broad scope not only covers water resources management, but also environmental management aspect such as pollution control, development planning and biodiversity conservation. The IRBM integrated approach is strongly supported by the Malaysian government. This is reflected in the Eighth Malaysia Plan (RMK-8), which encourages state government to establish water management bodies to ensure proper planning, monitoring, enforcement and management of water resources on a river basin basis. The Ninth Malaysia Plan (RMK-9), which also endorses IRBM and its integrated water resources management approach. Sungai Kedah Basin Management Plan (2007 – 2012) was produced to outlay the IRBM approach on Sungai Kedah basin, as one of the pilot projects of IRBM in Malaysia. The four key policies targeted in IRBM plan for Sungai Kedah include ensuring sufficient water, ensuring clean water, reduce flood risk, as well as conserve and develop river landscape. In order to support the Sungai Kedah IRBM, Sungai Raja as a small tributary to Sungai Kedah, is selected to be the study subject as to how the IRBM can be implemented. The proposed study shall concentrate on evaluating the water quality condition of Sungai Raja and prove through application of GIS and computer modelling, accurate technical and scientific inputs are crucial for IRBM implementation. The findings from this research study would serve as indicators to the performance of Sungai Kedah IRBM as well as providing lead to improvement and modification for more effective implementations.



Title: Biodiversity and Water Quality in Constructed Wetlands of Universiti Sains Malaysia, Seri Ampangan.
Nibong Tebal, Penang

Type: USM Short Term Grant

Year: On going

Amount of Grant: RM 40,000.00

Executive Summary :

Water pollution and eutrophication have been turning into serious problems since the middle of the 20th century. Scientists and researchers around the world are continually trying to find effective methods to control, prevent and treat the water pollution are sought. Natural and constructed wetlands are highly recommended to solve the problem by purifying the polluted water and rehabilitate ecological system. Utilising natural and local materials, the constructed wetland treatment is a cheaper alternative for water treatment and is far energy-efficient than mechanical facilities. The main function of constructed wetland is to utilize the natural processes involving wetland vegetation, soils and the associated microbial assemblages, which are the active agents, in the treatment process. Many studies on how to improve the water quality and increase nutrient and pathogen removal from various types of constructed wetland have been carried out. In Malaysia, and as many parts of the world, many studies have been carried out and a lot of improvements being made for better function of constructed wetlands. However, the relationship between the change in biodiversities of wetlands and the water quality has rarely been reported and studied. Very little is known of the biological integrity or “health” of a constructed wetland. Biological integrity is commonly defined as the ability to support and maintain a balanced, integrated and adaptive community of organisms having a species composition, diversity and functional organization comparable to those of natural habitats within the region. The goal for the research is to investigate the biological integrity through biological assessment (bio-assessment) by collecting field data from a constructed wetlands to determine the diversity and population of organism residing in it. At the same time, water quantity and quality parameters are also to be obtained. This will help to establish the relationship between hydrological change and biological integrity. Presently, the study was conducted on the constructed wetland of BIOECODS system in USM engineering campus. Monitoring and sampling works are currently on going on a weekly basis.



Title: Urban Flood Modelling for Ungauged Catchment: Case Study of Tanah Merah, Kelantan

Type: USM Short Term Grant

Year: On-going

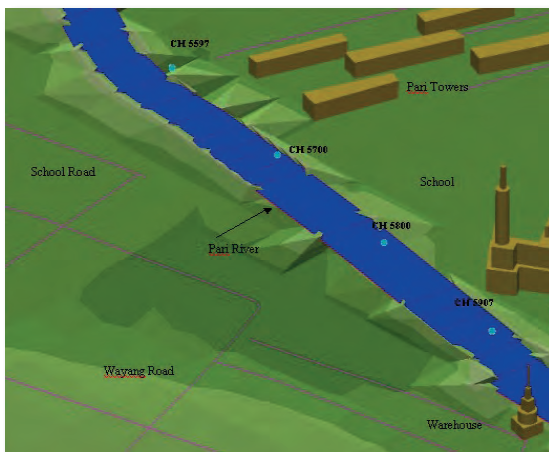
Amount of Grant: RM 40,000.00

Executive Summary :

Better technology produces better results. However, sophisticated/ complex computations might be overkill for assessment of floods under data scarce conditions. With realistic simplification, and good modelling practice, modeller can produce flood map of similar quality. In Malaysia, and many parts of the world, modelling ungauged catchment remains a daunting tasks due to lack of data for calibration and validation. Application of uncalibrated models will greatly affect the judgements and decisions made based on modelling results due to the huge uncertainties associated with uncalibrated models. The industry requires a standard procedure or best practices for flood inundation mapping in ungauged catchments. This study sets out to investigate two most important parameters in producing flood maps, i.e. ground model and hydrodynamic models. First, comparison of flood map between a coarse ground model (SRTM) and a detailed one (LiDAR) is made to determine if the trade-off is significant. Next comparison between 1D and 1D-2D hydrodynamic model is made to gauge the performance of both in monsoon flood modelling for an urban catchment. The results from this study will provide better insight for data preparation and model selection in flood modelling for ungauged catchment.



4.2 EXTERNAL GRANTS

**Title:**

Development of HEC – Series Program to Predict Sediment Movement for Rivers in Malaysia

Type:

IRPA RM-7

Funded by:

Ministry of Science, Technology and the Environment (MOSTE)

Year:

1997 - 2001

Amount of Grant:

RM 500,000.00

Executive Summary :

Four rivers were selected as study sites namely Pari River (Ipoh), Kerayong River (Kuala Lumpur), Kulim River (Kulim) and Malacca River (Mallaca City). Total bed material loads were collected from these rivers. The appraisals of the existing sediment transport equations showed that Yang, Ackers & White and Graf equations were suitable for the prediction of sediment transports in these rivers. A number of equations were also developed for the prediction of sediment transport rates using the collected sediment transport data especially for low to medium flows. During the study period, a 50-year flood occurred at Pari River on the 19th November 1997 causing structural damages to the rigid bank walls on both sides of the river especially at bends. Subsequently, the flood hydrograph was used to calibrate the HEC-6 model to predict the recorded flood water levels. A good agreement was found between the predicted and observed water levels using Yang equation. Another model namely, FLUVIAL-12 was also used to predict the erosion and deposition trends during the flood. The calibration results using Yang and Graf equations show that the FLUVIAL-12 model could well predict the observed erosion and deposition patterns along the river including at the bends. The results from the calibration of HEC-6 and FLUVIAL-12 models were then used for the rehabilitation work of Pari River.

A flood risk map was also developed for Pari River to represent the effect of the flood event by developing an ArcView GIS extension namely AVHEC-6.AVX integrating the HEC-6 model within GIS environment. The extension has the capability of analyzing the computed water surface profiles generated from HEC-6 model and producing a related flood map for Pari River in the ArcView GIS.



Title:

Peak Flow Attenuation Using Infiltration Engineering Systems and Storage Tank at USM's Perak Branch Campus

Type:

Research Contract

Funded by:

Department of Irrigation and Drainage (DID) Malaysia

Year:

1998 - 2000

Amount of Grant:

RM 800,000.00

Executive Summary :

This research presented the performances for the subsurface infiltration and storage tank systems which were used to control stormwater quantity in Engineering Campus Universiti Sains Malaysia, Tronoh, Perak. The purposes of this study were:

- (a) As a pilot research for Malaysian application
- (b) To study the efficiency of subsurface infiltration and storage tank to attenuate stormwater runoff
- (c) To study the effectiveness and efficiency of infiltration and storage tank technique to reduce flood woes in Malaysia
- (d) To analyses cost benefit of the systems
- (e) To provide a sustainable environment for urban communities

Three different infiltration and storage techniques had been selected based on the surrounding soil conditions. These systems were module infiltration system, loose rock infiltration system and module storage tank system. Data acquisition were carried out in two stages from July 2000 to March 2001 (Stage I) and from April 2001 to September 2001 (Stage II). Stage II was executed after few modifications had been made to improve system efficiency. Around 50 rainfall events were recorded and analysed. A guideline on infiltration and storage tank design for Malaysian application was produced as a part of the output of this study.



Title:

Feasibility Study and Detail Design of Flood Mitigation And Drainage Improvement in Chain Ferry, Seberang Perai, Pulau Pinang

Type:

Research Contract

Funded by:

Seberang Perai Municipal Council (MPSP)

Year:

1999

Amount of Grant:

RM 60,000.00

Executive Summary :

The study area covered the area of Chain Ferry, which is situated in Seberang Perai Utara district, Penang. The study area was bounded by Sungai Perai on the south and east and Butterworth Air Force Base to the north, covering a total area of 244.6 ha. The flood prone areas in Chain Ferry concentrated in the west of Federal Route 1 and its surrounding areas. Due to rapid development and lack of improvement for the existing drainage infrastructure, parts of the study area were affected by high tide and flash flood. The flood duration is typically short and usually occurs in the months of May and November. The flooding problems in Chain Ferry were caused by the inadequacy of existing drainage system and tidal effect. Moreover, the level of construction platform was lower than the desirable platform levels.

The principal objectives of the study included the following:

- (a) To study flooding and drainage problems in the study area.
- (b) To propose feasible flood mitigation and drainage enhancement works for immediate implementation in the study area.
- (c) To propose conceptual and preliminary designs of the proposed works including their layout and typical designs of components and to determine the land acquisition requirements.
- (d) To collect data and information required for the detailed design of the works.

As a result of investigation, REDAC had reviewed the existing drainage hydraulic capacity. It was found that most drainage has very little hydraulic capacity the sizes of drains were large. This was due to the low hydraulic gradient caused by the flat topology of the study area and heavy tidal influence. Based on this findings, the several pumping stations were proposed to assist in water discharge. This option was viewed as the most cost-effective measure due to the saturated development and space constrain of the site.



Title:

Feasibility Study and Detail Design of Flood Mitigation and Drainage Improvement in Taman Seri Rambai, Taman Makok and Taman Desa Damai, Seberang Perai Tengah, Pulau Pinang

Type:

Research Contract

Funded by:

Seberang Perai Municipal Council (MPSP)

Year:

1999

Project Cost:

RM 90,000.00

Executive Summary :

The study area covered the area of Taman Seri Rambai, Taman Makok, Taman Desa Damai, Taman Sungai Rambai, Taman Sri Jaya, Taman Padang Lallang, Taman Mutiara and its surrounding. The study area was approximately 343 ha and drained by two parallel channels – Sungai Rambai and Parit 4. Sungai Rambai has two main upstream tributaries and discharges into Sungai Juru through a tidal gate at Juru Dam. Parit 4 is an extension of Sungai Permatang Rotan and has two gated outlets to Sungai Juru. Sungai Rambai and Parit 4 are linked by three cross drains. Frequent flooding in Lembah Sungai Rambai and its surroundings has been a long-standing issue, which is of considerable concern to the relevant authorities. The components of the proposed flood mitigation schemes consisted of bunding along Sungai Rambai, upgrading Parit 4 and trunk drains, constructing monsoon drains, flood control gates and pumping system, as well as installing gross pollutant traps (GPT) and sediment basin.

Three alternatives had been proposed in this study. Alternative 1 was a pumping-based solution. Detention facilities were not included in this alternative. Alternative 2 was a detention-based solution. This alternative aimed for the zero peak discharge and thus, the main waterways will not be burden by the runoff from the study area. Rainfall harvesting was also suggested to further reduce the volume of stormwater in the drains during rainfall events (Alternative 3).

**Title:**

Feasibility Study and Detail Design of Flood Mitigation and Drainage Improvement in Taman Sentul, Taman Sentul Jaya, Taman Pinang and Taman Mangga, Juru, Seberang Perai Tengah, Pulau Pinang

Type:

Research Contract

Funded by:

Seberang Perai Municipal Council (MPSP)

Year:

1999

Amount of Grant:

RM 130,000.00

Executive Summary :

The study area consisted of the areas in Taman Pinang, Taman Mangga, Taman Sentul and Taman Sentul Jaya, which belong to the Seberang Perai Tengah district. This area was located near to Parit No. 5 and affected by the tidal influence. The flood woes in the study area had been a long-standing issue since 1990's. The study area was frequently flooded whenever it rains heavily for duration of more than 1 hour. Frequent floods had caused extensive damage and inconvenience to the community. The flood prone areas in the study area concentrated in the west of Federal Route 1 and its surrounding areas. Due to the rapid development and lack of improvement for the existing drainage infrastructure, parts of the study area was affected by high tide and flash flood. The duration of flooding was short and it happened in certain period of the year (mid of May and November). The flooding problems in the study area were caused by the inadequacy of existing drainage system and tidal effect. Moreover, the level of construction platform was lower than the desirable platform levels.

The principal objectives of the study were:

- (a) To study the flooding and drainage problems in the project area.
- (b) To propose feasible flood mitigation and drainage enhancement works for immediate implementation in the project area.
- (c) To propose conceptual and preliminary designs of the proposed works including their layout and typical designs of components and to determine the land acquisition requirements.
- (d) To collect data and information required for the detailed design of the works.

The proposed detailed planning and design consisted of drainage system (drains and bund), structures (culverts, control gates etc.), pumping stations and river improvement. These improvement were presented in a report as well as engineering drawings to facilitate future construction and implementation of the flood mitigation works.



Title: Feasibility Study and Detailed Design of Flood Mitigation And Drainage Improvement In Valdor, Pulau Pinang

Type: Research Contract

Funded by: Seberang Perai Municipal Council (MPSP)

Year: 1999

Executive Summary :

Valdor village and its surrounding areas, which covered an area of approximately 160 hectares, was situated in Mukim 3, Seberang Perai Selatan. This area had been served by two main outlet drains namely Parit Pertanian and Parit Paya Mahang, which were maintained by Department of Irrigation and Drainage (DID). The drainage problems encountered by the village were partly due to the absence of proper network of internal drains within the village. The flooding problem had worsened with the rapid increase in development and the change in land use pattern, i.e. from a predominantly rural and agricultural/farm setting to that of a newly developed settlement area.

The principal objectives of the study were listed as follows:

- To study the flooding and drainage problems in the study area.
- To propose feasible flood mitigation and drainage enhancement works for immediate implementation to cater for the study area.
- To propose conceptual and preliminary designs of the proposed works including their layout and typical designs of components and to determine the land acquisition requirements.
- To collect data and information required for the detailed design of the works.

Four alternatives were proposed in this study, which could be categorised into two main categories namely, Conventional Drainage System (Alternatives I and III) and Ecological Drainage System (Alternatives II and IV). Both structural and non-structural flood mitigation measures had been proposed to mitigate the flood problems.



Title: Environmental Management Plan for Universiti Teknologi Petronas

Type: Research Contract

Funded by: Institute of Technology, Petronas Sdn. Bhd.

Year: 1999-2002

Project Cost: RM 300,000.00

Executive Summary :

Environmental Management Plan (EMP) is an environmental requirement to minimize impact of development to the environment. This plan relates the Environmental Impact Assessment (EIA) of the development project to the policies of regulating bodies. The Environmental Management Plan also outlined actions to be taken to ensure proper environmental observations by all parties involved in the project. USM was appointed as the EMP consultant for the development project of Universiti Teknologi Petronas and thus was responsible to monitor the environmental adherence throughout the construction period until the project was handed over to the owner.

EMP ensures that the following impacts are minimized and control within the desirable limits and comply with all applicable standard and guidelines:

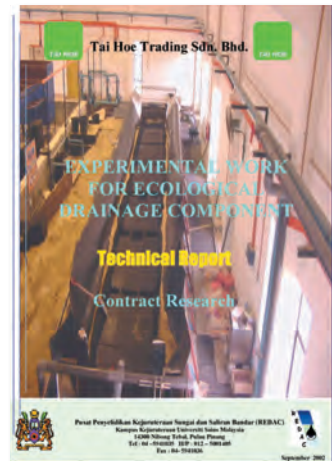
- (a) Soil erosion and sedimentation
- (b) Impact on water quality/pollution
- (c) Impact on air quality/pollution
- (d) Noise pollution
- (e) Impact on ecology
- (f) Impact from construction traffic



USM was responsible in preparing EMP report, conduct monitoring and auditing, conduct environmental training to contractors and site inspections throughout the construction period. The scope of works included the following:

- (a) Preparing Environmental Management Plan (EMP) as a proper environmental approach during project implementation to conform with approved EIA report by DOE, EIA Condition's Approval from DOE and related Authorities and Contract Specifications.
- (b) Review the mitigation and abatement measures proposed in the EIA report, and Erosion and Sediment Control Plan (ESCP) by contractors.
- (c) To set out a comprehensive program which forms the basis for implementing environment mitigation measures, environment monitoring and environment auditing of the construction works by the Contractor.
- (d) To ensure that the Contractor engaged by the Government comply with all applicable environmental standard and guidelines, legislative requirements, limit values and other relevant conditions related to the environments in the implementation of the project.
- (e) To specify a detailed environment monitoring and auditing program to ensure that the Contractor and all Sub-contractors comply with all stipulated requirements throughout the duration of the project.
- (f) To ensure all activities and operations of the Contractor are protected from any environmental impacts throughout the construction phase of the project. It shall also include but not limited to environmental monitoring, conservation and preservation and auditing activities.

Through close coordination and cooperation, the new campus of UTP was successfully completed in 2002. The EMP was closely implemented at all stages of construction under the monitoring and guidance of USM.



Title: Experimental Work for Ecological Drainage Component

Type: Research Contract

Funded by: Tai Hoe Trading Sdn. Bhd.

Year: 2000

Project Cost: RM 50,000.00

Executive Summary :

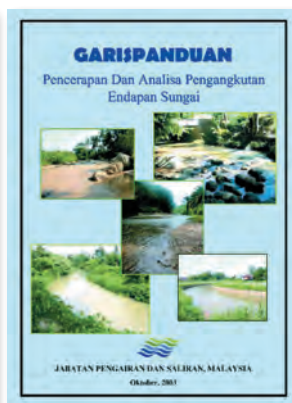
Rapid development in Malaysia with the construction of new towns may change the hydrologic and hydraulic characteristics of previously rural catchments. Flash flood and lower replenishment of groundwater may occur downstream of the new development areas as a result of increase in impermeable areas. The main feature of ecological drainage is the use of subsurface drainage modules acting as both stormwater conveyor and attenuation agent. This report contains the study of drainage modules in order to determine their suitability and workability as well as to confirm the specifications of these components under local condition.

The objectives of this study are:

- To test the hydraulic capacity of the drainage module
- To check the water quality improvement capability of the drainage module

The results show that the drainage module should be designed as pipe flow and the resulting turbulence causes the DO level to increase with the distance as flow travels downstream.





Title: River Sediment Data Collection and Analysis

Type: Research Contract

Funded by: Department of Irrigation and Drainage (DID)

Year: 2000 - 2003

Project Cost: RM 410,000.00

Executive Summary :

This project report consisted of three Volumes and a guideline as stated below :

- (a) Volume I: Main Report
- (b) Volume II: Sediment Transport Equation Assessment
- (c) Volume III: Sediment Size Distribution Curve
- (d) Guideline: River Sediment Data Collection and Analysis

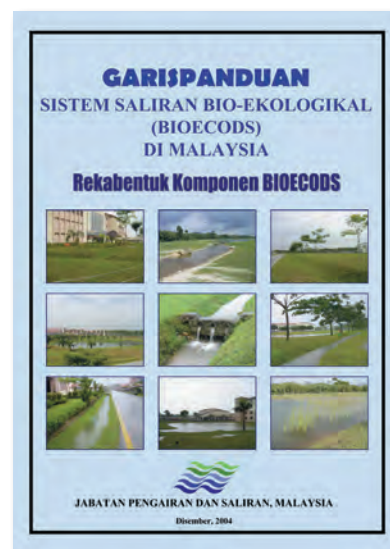
The principal objectives of the Study included the following:

- (a) Establishment of a sediment transport database for alluvial rivers within a range of low and high flows for a different landuse and development.
- (b) Establishment of relationship between flows and sediment loads for the assessment of the stability of river channel due to erosion and deposition for different type of catchment developments
- (c) Establishment of relationship between flows and sediment loads for design and evaluation of new and existing flood mitigation projects.

Data collections including suspended load, bed load, bed material and flow discharge had been carried out during the Study. A total of 122 sets of data were obtained for the period of September 2000 to October 2002. The study sites consisted of four rivers which were situated at Kinta River Catchment, namely Kinta River, Pari River, Raia River and Kampar River. The sites for this Study were chosen based on the following criteria :

- (a) Natural reach: Undeveloped upper or middle reach (< 30 % Catchment Development) - Kampar River@ KM34
- (b) Natural reach: Developed middle reach (> 30 % Catchment Development) - Raia River @ Kampung Tanjung and Batu Gajah
- (c) Modified reach: Developed middle reach (> 30% Catchment Development) - Kinta River@ Ipoh, Pari River @ Buntong and Manjoi

The data collection includes flow discharge, bed load, water-surface slope and bed material. Collected sediments were analysed in laboratory through various testing such as dry sieve to determine the bed material size distribution and mean sediment size (d₅₀). Therefore, sediment characteristics of the studied river were determined. The evaluations for a total of 346 data sets based on median sediment size (d₅₀) have been performed using eight commonly-used sediment transport equations. The performances of the equations were measured using the discrepancy ratio (DR), which is the ratio of the predicted load to measured load (DR=predicted/measured). In this study, a discrepancy ratio of 0.5 to 2.0 (DR = 0.5-2.0) was used as a criterion in the evaluation of the selected equations. This information is useful for future sediment transport modelling or other sediment related analyses.



Title: Application of Bio-Ecological Drainage System in Malaysia

Type: Research Contract

Funded by: Department of Irrigation and Drainage (DID)

Year: 2000 - 2004

Project Cost: RM 2,900,000.00

Executive Summary :

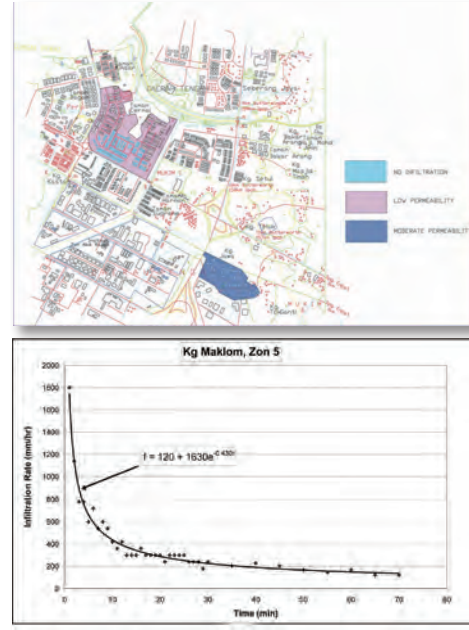
The final report consisted of four volumes and a monograph as stated below :

- (a) Executive Summary
- (b) Volume I: Concepts, Design and Construction
- (c) Volume II: Data Collection and Assessment
- (d) Volume III: Publications
- (e) Guideline: BIOECODS Design

Through smart partnership of Department of Irrigation and Drainage and Universiti Sains Malaysia, a new stormwater drainage system was initiated. The Bio-Ecological Drainage System (BIOECODS) was meant to be a pilot project that meets the requirement of Urban Storm Water Management Manual for Malaysia (MSMA). It was designed for both water quantity and quality controls. As result of the partnership, BIOECODS was constructed at Engineering Campus, Universiti Sains Malaysia, Nibong Tebal, Pulau Pinang and completed in December 2002. BIOECODS represented an alternative to conventional stormwater management practice and was designed as an environmental-friendly system based on "Control-at-Source" concept. The objectives of this pilot project were:

- (a) Infiltration of stormwater from building, road and other impermeable areas
- (b) Flow retardation of stormwater runoff
- (c) Stormwater treatment

The components of BIOECODS system found in this site were ecological grassed swales, dry ponds and an ecological pond consisting of wetpond, detention pond, wetland, wading river and recreational pond. Three types of ecological swales were constructed namely Type A, Type B and Type C depending on the number of modules available underneath the swale. Stormwater runoff was conveyed by ecological swales and dry ponds to wet pond, detention pond and finally wetland for further treatment. The end product was expected to improve the aesthetic values of the USM Engineering Campus with the existence of the "Crystal Clear Blue Water Lake" at the downstream end of the system. Throughout the project, REDAC acted as the designer of the system and was responsible for site supervision of the entire construction. Since completion, the BIOECODS was handed over to USM, who in turn entrusted the responsibility of maintaining the system to REDAC. Now, REDAC is continuingly maintaining, and monitoring the system to establish important stormwater database for the country.



Title: Development of Soil Classification With Respect to Infiltration Capacity For Major Cities In Malaysia

Type: IRPA RM-8

Funded by: Ministry of Science, Technology and the Environment (MOSTE)

Year: 2002 - 2005

Amount of Grant: RM 170,000.00

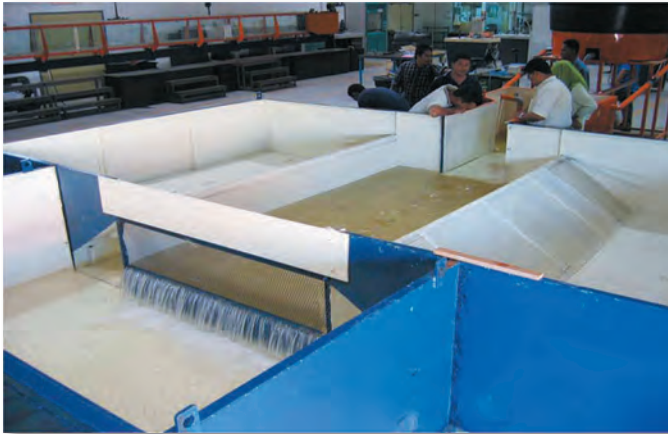
Executive Summary :

Urbanization eliminates the natural storages of the watershed and changes permeable surface to impermeable surface such as pavement and buildings roof. This leads to rapid increment in peak flow and runoff volume during rainfall events. Consequently, flash floods happen in urban areas during short and intense rainfall. Department of Irrigation and Drainage Malaysia (DID) had introduced the application of "at-source control" approach to solve current flood problems in urban areas in year 2000. Infiltration system was one of methods that was proposed in Urban Stormwater Management Manual for Malaysia (MSMA) to control peak flows and runoff volume.

The size of infiltration system and time for emptying the system are sensitive to infiltration coefficient. Hence, any uncertainty in the selection of infiltration coefficient value may lead to significant inaccuracy in the design of the system. However, infiltration coefficient is highly dependent on the in-situ soil condition. Factors influencing the infiltration rate include the condition of the soil surface and its vegetative cover, the properties of the soil (such as porosity and hydraulic conductivity), the current moisture content of the soil and the soil strata.

Unfortunately, database on infiltration coefficients for local soil conditions have yet to be established. Without this database, designs have to be based on overseas infiltration coefficient (such as USCS soil classification for USA), which may not be applicable for Malaysian soil at all. In fact, a comprehensive and systematic database of soil classification with respect to its infiltration capacity for major cities in Malaysia is essential not only for infiltration system designs but also for studying the applicable and effectiveness of infiltration system to control floods in both the technical and economical aspects.

Based on the results of the infiltration tests carried out in this study, infiltration maps were plotted for Butterworth and Universiti Sains Malaysia (USM) Engineering Campus, Nibong Tebal. The maps were plotted according to the infiltration capacity of soil type for each area. The final output would provide invaluable information for stormwater engineers when designing stormwater infiltration facilities in the future.



Title: The Development of Engineered Sediment Trap for Conventional Drainage System

Type: IRPA RM-8

Funded by: Ministry of Science, Technology and the Environment (MOSTE)

Year: 2002 - 2005

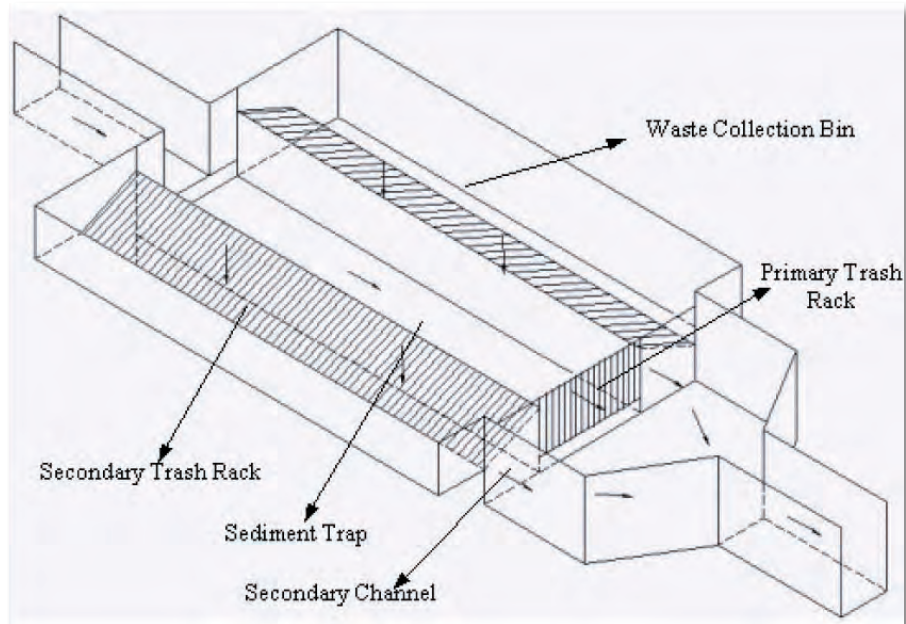
Amount of Grant: RM 150,000.00

Executive Summary :

Over the past few decades, human activities such as industrialization and urbanization have led to the increase in magnitude of water pollution and thickness of sediment deposition in the exiting drainage system of the country. This phenomenon has reduced the effectiveness of the urban drainage system that is built to convey surface runoff. Therefore, a study on sediment size characteristics in existing concrete drain is essential at a preliminary stage to develop a suitable solution for the maintenance of a conventional drainage system and hence avoids the possibility of flash flood due to excessive sediment deposition in the drains.

Surveys had been carried out to determine suitable sites for the study. As the result, eight sites in urban area in Malaysia had been selected to determine the sediment size characteristics in existing concrete drains. The sites were located at Alor Setar, Ipoh, Johor Bahru, Kota Bahru and four sites in Seberang Perai, i.e. Chain Ferry, Bandar Seberang Jaya, Taman Inderwasih Perai and Taman Perindustrian Bukit Tengah. The results of sediment deposition data collection showed that sand and gravel were the major components that were found in the sediment samples. This indicated that the sediment size distribution in study sites was mainly non-cohesive. The average size of sediment in eight study sites varied from 0.5 to 1.2 mm.

In order to tackle this sediment issue, the study designed and proposed a gross pollutant trap (GPT) to trap sediment and gross pollutants of stormwater coming from roofs, yards, roads or lawns in an urban area. Additionally, the proposed GPT would include pollutants separation from flows by the energy of the water flow (self-cleansing method). GPT is an engineered sediment trap designed to catch and remove litter, debris, and coarse sediment

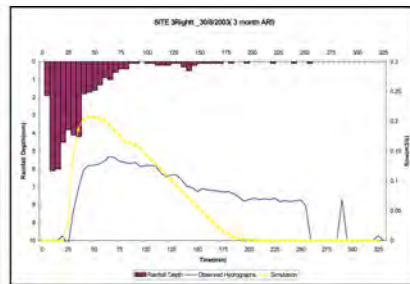
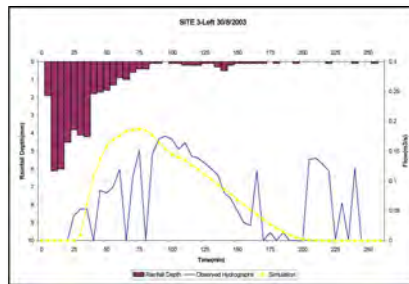
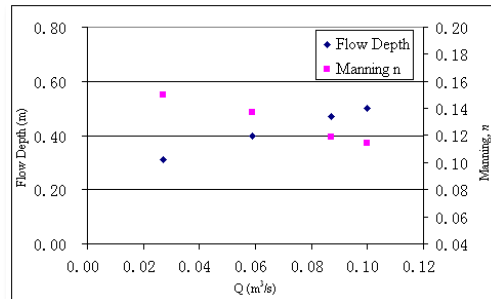


from runoff. The main function of GPT is to keep coarse sediment out of ponds, protecting the vegetation at the head of the pond from the smothering effects of sediment. It may also be used as the pretreatment for flow into a pond or wetland to confine the area of deposition of coarse sediments. Besides coarse sediment, traps will also provide some reduction in other pollutants with the installation of an additional device such as the removal of particulate nutrients, trace metal, oil and grease, as well as reduction of bacteria and dissolved oxygen-demanding substances.

The GPT is an incorporated system consisting of silt trap a gross pollutant trap, which is capable to trap bed load as well as removal solid waste from stormwater. Basically, it consists of two compartments namely on-line trap and off-line trap.

The on-line trap is referred to a sediment trap combined with a primary trash rack, which is constructed inline with the channel flow direction to treat stormwater at low flow season. It comprises a uniform channel with an expansion extended from the existing drain and with a drop at sediment trap to reduce the flow velocity of the channel. It is essential to slow down the flow velocity to encourage the settling process for sediment in particular. During low flows, turbulence is not significant and the pollutant will remain in its original characteristics. Consequently, pollutant that is denser than water will settle or sink at the bottom of the sediment trap, whilst floating pollutants will be removed from stormwater by the primary trash rack. This on-line trap was designed for up to stormwater quality treatment recurrent interval (3 month ARI).

Off-line traps are provided at the both sides of the on-line traps intends to treat stormwater during events exceeding 3 month ARI to cater to the large quantity of stormwater runoff. Besides, the off-line trap also functions as the secondary trap or back up trap, which is responsible to treat any stormwater runoff whenever the on-line trap is clogged up. Thus, the excess water will overspill sideways into off-line trap, pass through the secondary channel and then return into the main channel as outflow. Additionally, off-line trap channel is designed using self-cleaning principle. The pollutants will be intercepted by the screen and forced down it by a combination of the momentum of the water and gravity, until it comes to rest in a waste collection bin and allowed to dry out for removal.



Title: Hydraulic Capacity of Ecological Drainage System

Type: IRPA RM-8

Funded by: Ministry of Science, Technology and the Environment (MOSTE)

Year: 2002 - 2005

Amount of Grant: RM 140,000.00

Executive Summary :

The objectives of the study were:

- To determine engineering parameters for design of ecological drainage system
- To determine hydraulic capacity of ecological drainage system
- To investigate effectiveness of ecological drainage system in peak discharge control

The major achievements in this study were the verification of Manning's n values for ecological drainage (bio-retention swales), calibration of required parameters for SWMM modeling, and confirmation of swale capability in flow attenuation for various rainfall events. The results confirmed the flow retarding effect of swale due to the presence of grass along its hydraulic boundary. This was based on record observations and analyses of hydraulic functions at selected sites of the BIOECODS in USM engineering campus over a five-year period (2003 – 2007). This period of study covered various magnitude of rainfall events including 1-year, 2-year, 5-year, 10-year and 50-year Average Recurrence Interval (ARI) events.



Title:

Feasibility Study of Flood Mitigation and Drainage Improvement in Kampung Tersusun, Juru, Penang

Type:

Research Contract

Funded by:

Seberang Perai Municipal Council (MPSP)

Year:

2003

Project Cost:

RM 90,000.00

Executive Summary :

The Study area Kampung Tersusun, Juru covered an area of 2.9 ha, which was situated in district of Seberang Perai Tengah. Frequent flooding in the Study area had been a long-standing issue, which was of considerable concern to the local government, MPSP. Consequently, River Engineering and Urban Drainage Research Centre (REDAC) had been appointed by MPSP to carry out a feasibility study on flood mitigation and drainage improvement at the study area. The study would review the actual situation and the subsequent immediate need for establishment of proper drainage system in the study area.

The objectives of this were:

- (a) To study the flooding and drainage problems in the Study area.
- (b) To propose feasible flood mitigation and drainage enhancement works for immediate implementation in the Study area.
- (c) To propose conceptual and preliminary designs of the proposed works including their layout and typical designs of components and to determine the land acquisition requirements.
- (d) To collect data and information required for the detailed design of the works.

Three flood mitigation alternatives were proposed with two main components namely construction of pumping system and drainage upgrading.



Title:

Feasibility Study and Detailed Design of Flood Mitigation and Drainage Improvement in Perai Industrial Complex

Type:

Research Contract

Funded by:

Seberang Perai Municipal Council (MPSP)

Year:

2003-2004

Project Cost:

RM 150,000.00

Executive Summary :

Seberang Perai, Penang is divided into three areas namely Seberang Perai Utara, Seberang Perai Tengah and Seberang Perai Selatan. The study area was situated in Mukim 1, the district of Seberang Perai Tengah and was known as the Perai Industrial Complex. Perai Industrial Complex was developed in early 70's by Penang Development Corporation (PDC) and was known as the biggest industrial site in Malaysia. This area covered Perai Industrial Park (313.2 ha) and Perai Free Industrial Zone (127.9 ha). MPSP intended to upgrade the stormwater drainage facilities for quantity and quality control in the study and surrounding area. Therefore, REDAC was engaged for this feasibility study on drainage improvement in Perai Industrial Complex to study the drainage system and the water pollution problems.

The principle objectives of the study included the following:

- (a) To determine and evaluate the existing drainage systems and water pollution problems in the study area.
- (b) To propose the drainage improvement plan for existing quantity and quality controls in the study area.
- (c) To develop the conceptual and preliminary design including layout design and typical components and the need of land acquisition.
- (d) To collect data and information for detail design.

The preliminary wastewater quality study was conducted from November 2003 until January 2004. 18 stations were established throughout the study area. Twenty three (23) parameters including those physical, chemical and biological categories were monitored and the results were presented against the Standard B, EQA. The XP-SWMM drainage model was used to study the hydraulic performance of the drainage in this area. It was found that while most drains were large in size, the hydraulic capacity is low due to low gradient and tidal effect. Subsequently, two alternatives were proposed for flood mitigation and water quality improvement for the study area.

**Title:**

Flood Mitigation and Detailed Design for Sungai Air Salak, Melaka

Type:

Research Contract

Client:

Perunding Azman, Ooi & Rao Sdn. Bhd.

Funded by:

Department of Irrigation and Drainage (DID), Melaka

Year:

2003-2004

Project Cost:

RM 90,000.00

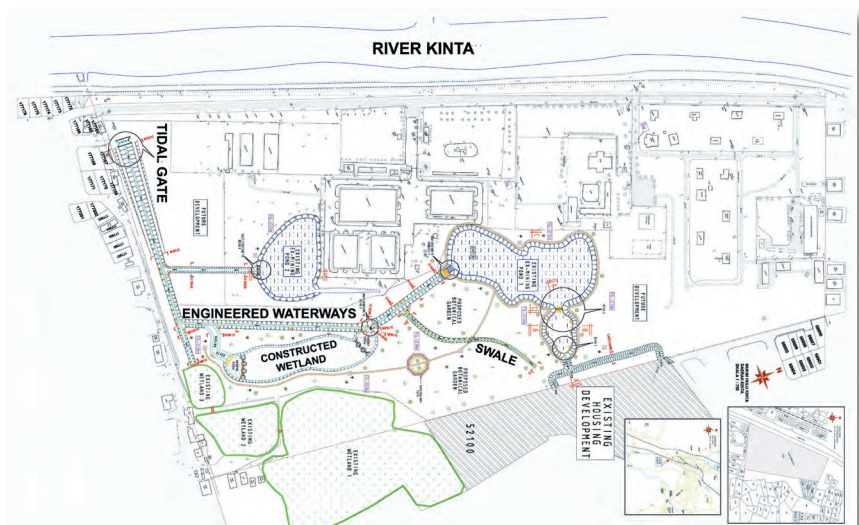
Executive Summary :

This study was initiated to tackle the issue of overbank flooding in Sungai Air Salak, Melaka. The flood was caused by inadequate river section to cater to the increased runoff and undersized crossings. Future development in this catchment area may further aggravate the situation. As such, immediate measure for flood mitigation was required. Through this study, various data collection and field works were carried out including site visits, field investigation and general survey of the waterways. The collected information and data were then reviewed, sorted and cleaned for further analyses. Then, the study proceeded with reviewing and evaluating the existing river system by carrying out hydrological and hydraulic analyses including numerical modelling. Finally, river improvement alternatives were formulated based on MSMA and other DID requirements.

The principal objectives of the study included the following:

- (a) To study the flooding along the river.
- (b) To propose feasible flood mitigation works for immediate implementation to cater for the river discharge.
- (c) To prepare detailed designs of the proposed works and to determine the land acquisition requirements.
- (d) To collect data and information required for the work.

Subsequently three river upgrading plans were proposed as alternatives based on the analyses and investigation of this study.



Title: Rehabilitation of Existing Wetlands and Mining Ponds as an Ecological Park at DID's Mechanical Section, Ipoh

Type: Research Contract

Funded by: Department of Irrigation and Drainage (DID)

Year: 2005

Project Cost: RM 210,000.00

Executive Summary :

In line with the implementation of the Urban Stormwater Management Manual for Malaysia (MSMA), the project would be a showcase for development of ex-mining ponds as stormwater facilities in Perak and throughout Malaysia. The study was a pilot project that rehabilitates the ex-mining pond into multi-functional facility, which provide recreational, water reuse and stormwater retention functions. The study area consisted of DID Mechanical Section, covering an area of 88 acres in the Kinta District, Ipoh, Perak. The study area was situated on a former ex-mining land which consisted of sandy soil and was sparsely vegetated. The main features of the site were the two ex-mining ponds, which were located in the vicinity of the buildings. There were also swampy areas along the eastern border of the site and partially extended out of the premis boundary. The existing drainage system was based on rapid disposal approach, which disposes the surface runoff to the roadside concrete drain before discharging into River Kinta via a nearby pump station. The surface runoff from the open area flowed into the two main ex-mining ponds which were connected to the River Kinta by earth drain. The ex-mining pond and the existing wetland (swampy areas) were to be rehabilitated and restored into ecological ponds with multi-functional uses. The planning and design into the restoration and rehabilitation of the ecological ponds were based on the MSMA and fulfill the requirement of water quantity and quality control.



The objectives of this Study were 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 stormwater and recreational purposes.

The main components of the proposed integrated storm water, the Ex-mining pond 1, was designed as a regional pond to control both water quantity and quality from the study site and the surrounding areas. The conveyance system selected for the site was engineered waterway with features mimicking natural rivers. Stormwater runoff from the botanical garden was conveyed to the engineered waterway via swale. Further treatment of stormwater runoff was provided through a constructed wetland connected to the Ex-Mining Pond 1 via the engineered waterway. The existing wetland was improved to provide treatment for runoff from surrounding areas. The Ex-Mining Pond 2 was designed as a community pond to control both water quantity and quality from the study site. An automatic tidal gate was introduced at the downstream end before the runoff was discharged to Sungai Kinta. The design of the project was completely based on MSMA by providing a series of treatment train for both stormwater quantity and quality control.

The entire rehabilitation project was completed in 2007, with REDAC acting as advisor to the Government. This rehabilitation project continues to provide an excellent example of stormwater management and rehabilitation throughout Malaysia.


Title:

Independent Checker's on Stormwater Management for Kolej Sains Kesihatan Bersekutu Johor, Johor Bahru, Johor Darul Takzim

Type:

Research Contract

Client:

Ibuzawa Corporation Sdn. Bhd.

Funded by:

Public Works Department (JKR)

Year:

2003-2004

Project Cost:

RM 110,000.00

Executive Summary :

River Engineering and Urban Drainage Research Centre (REDAC) was appointed by the turnkey contractor, Ibuzawa Corporation Sdn. Bhd. to act as an independent checker for the construction of stormwater management facilities for Kolej Sains Kesihatan Bersekutu Johor. The Project area covered an area of 30 acres. The development was located on Lot 8173 Mukim Tebrau, Daerah Johor Bahru, Johor Darul Takzim. It was located in the East of Jalan Kempas Baru, on a hilly area. The main objective of this project was to evaluate and review the planning and design of stormwater management facilities and erosion and sedimentation control plan of the Project and to ensure that all the works are done in accordance with the Department of Irrigation and Drainage's Urban Stormwater Management Manual for Malaysia (MSMA). REDAC advised the consultant accordingly on the requirements of MSMA and recommended methods of meeting such requirements. Subsequently the project was completed in 2004 and is continuingly servicing as an academic institution.





Title:

Design Option of the Flood Mitigation Plan of Sg. Muda, Sungai Muda, Kedah

Type:

Research Contract

Funded by:

Department of Irrigation and Drainage (DID)

Year:

2006

Project Cost:

RM 200,000.00

Executive Summary :

The Flood Control Remediation Plan (FCRP) of Sg Muda was reviewed to study the possibility of enhancing the proposed design. The objectives of this review were to:

- (a) ensure that design cross-sections and alignment of the main river channel are economic, effective and environmentally sound;
- (b) propose alternative designs for identified locations to meet the above requirements;
- (c) examine the long term river behaviour through model studies to minimise expensive repair works in future resulting from the new alignment.

By constructing hydrologic and hydraulic model of the proposed design, REDAC, working in collaboration with Prof Pierre Y. Julien, a river engineering expert from the Colorado State University, was able to put forward several important findings. The current bund height proposed by the consultant was based on a 50 year ARI design discharge of 1,815 cumecs plus freeboard. This design was found to be highly conservative and would surpass the actual flows with a return period of exceeding 100 years. The main conclusion of this review was that the design of the bund height shall be based on the maximum water level of the 2003 flood discharge of 1,340 cumecs plus a one meter freeboard. The proposed channel widening in Alternative 2 of the consultant's proposal also appears not to be necessary. Channel widening would correspond to lowering of the bund height significantly if retained.

In addition, a plan to address the sand and gravel mining issues on Sg Muda was also strongly recommended to ensure:

- (a) stability of the proposed river bank protection structures;
- (b) stability of the bridge piers at Ladang Victoria;
- (a) operations of irrigation pumping stations.

Channel realignment was proposed at two sites to increase flood conveyance and further lower the proposed bund height. In-stream mining shall not be allowed between Ladang Victoria and the Muda barrage. Off-stream mining at a minimum distance of 50 m from the river bank could be permitted instead. With a design discharge reduction of 25%, this study showed the potential for a very significant cost saving of this FCRP for Sg. Muda. These recommendations were all based on Fluvial-12 sediment transport modelling by REDAC. REDAC also recommended that a more detailed analysis of the reduced bund elevation to be carry out to study the effects of the reduced design flood discharge and the proposed realignment. Also, the details on the locations and sand mining volumes extractable from off-stream mining activities shall be examined.



Title: Drainage Master Plan for Tanjung Malim, Perak

Type: Research Contract

Funded by: Majlis Daerah Tanjung Malim (MDTM)

Year: 2006-2007

Project Cost: RM 440,000.00

Executive Summary :

The study was commissioned by Tanjung Malim District Council (MDTM) to address the drainage issues and problems in Tanjung Malim city area. This study shall also cover the immediate surrounding area set to undergo landuse transformation from agriculture to commercial and industrial area as plan in the structure plan 2010. The total study site covered an area of almost 2000 ha consisting of four main river catchment, all of which were tributaries of the Sungai Bernam catchment.

The objectives of the study were:

- (a) To formulate Drainage Master Plan for the project area up to the planning horizon of the structure plan covering the following components: i) trunk drains and secondary drains in the existing built-up areas of the study area; ii) trunk drains for the remaining areas of the study area.
- (b) To study the flooding and drainage problems in the study area.
- (c) To propose conceptual and preliminary designs of the proposed drainage improvement works including their layout and typical designs of components and to determine the land acquisition requirements.
- (d) To propose feasible detailed design for urgent flood mitigation and drainage enhancement works for immediate implementation in the project area.

REDAC carried out this study by first conducting thorough stormwater asset inventory, which was recorded in GIS format. Water quality monitoring and rapid ecological assessment were conducted during field works. These data were sorted out, filtered, cleaned and were used in further analyses. Hydrodynamic model was set up to evaluate the performance of the existing river and drainage system, and to identify the causes of any current issues. Future development scenario was also considered. Finally, stormwater master plan was drafted based on the findings of the analyses. The master plan was thoroughly debated several rounds at local council level involving all stakeholders before being finalised. The final master plan included both structural and non-structural parts measures to control and manage stormwater efficiently. As part of the scope of work, REDAC also prepared a full set of detailed engineering design for the immediate flood mitigation work of Sungai Berop (one of the four river system in the study area).



Title: Consultancy Services to Evaluate the Proposed Flood Preventive Works to be Taken Subsequent to the December 2006 – January 2007 Floods Study on River

Type: Research Contract

Funded by: Economic Planning Unit, Prime Minister's Department

Year: 2007

Project Cost: RM 200,000.00

Executive Summary :

On the 23rd May, 2007, the Government of Malaysia had agreed on an RM941.5 million flood preventive works to address the effects of extreme floods, which hit the southern states of Johor, Melaka, Negeri Sembilan and Pahang between 19th and 24th December, 2006 and between 11th and 17th January, 2007. On 3rd July, 2007, USAINS Holding Sdn Bhd through River Engineering and Urban Drainage Research Centre (REDAC) was officially appointed to undertake a technical evaluation of the proposed flood preventive works identified by Department of Irrigation and Drainage (DID) and Public Works Department (JKR) for the prevention of floods in affected states.

The objective of the study was to carry out a technical evaluation of the proposed immediate works, amounting to RM 941.5 million, as identified by Department of Irrigation and Drainage (DID) and Public Works Department (JKR) for the prevention of floods in the affected states of Malaysia as a result of the December 2006-January 2007. Evaluation team were dispatched to the states involved namely Johor and Sabah, to evaluate the actual flood damage, urgency, appropriateness and cost-beneficial of the recommended projects by DID and JKR. On the advice of REDAC, the recommended works were prioritised. Minor changes on the nature of mitigation and repair works were made, while some urgent works being initially overlooked or left out were relisted. Finally, the Cabinet approved the proposal and the much needed fund were released to support the flood recovery in affected areas.



Title: Drainage Improvement from Maktab Perguruan Melayu Melaka to Taman Peringgiti Jaya, Melaka

Type: Research Contract

Funded by: Department of Irrigation and Drainage (DID)

Year: 2007-2008

Project Cost: RM 260,000.00

Executive Summary :

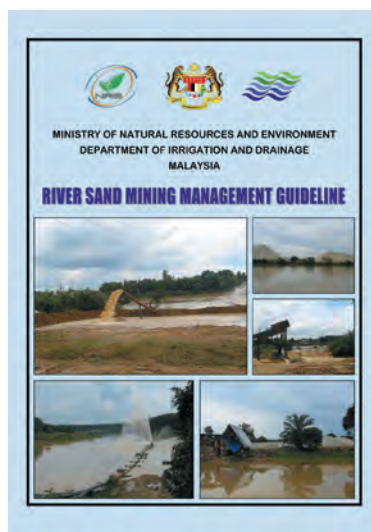
The Study covers a catchment area of 133.5 ha including Institut Perguruan Perempuan Melayu (IPPM) Melaka. This area is surrounded by housing estates and villages, including Kampung Durian Daun Dalam, Kampung Mata Kucing, Taman Peringgiti Jaya and Taman Seri Cempaka. The main drain that pass through the catchment area evolved from earth drain at upstream to concrete drain in the institute Perguruan's compound, and exited into earth drain again before discharge to Sungai Melaka. As a result of undersized local drains and culvert, low platform level in the Study Area, tidal effects, lack of maintenance for the existing drainage system caused by shrubs, sludge and rubbish, flash floods occur in most parts of the study area. The floods usually last more than 2 hours, and the current facilities can no longer withstand the increasing runoff. In addition, the contribution of grey water from existing residential areas has caused degradation of water quality in the existing water body, and therefore stormwater management facilities are needed to counter for the flooding faced by the population in this area and to ensure clean discharge water to Sungai Melaka. The Stormwater Management Facilities to be constructed are for an area alongside the main drain which often facing flooding problems.



A 2.28 KM in length and 7 m in width drain from Institute Perguruan Perempuan Melayu (IPPM) Melaka to Taman Peringgai Jaya have been identified for the construction of stormwater management facilities. The objectives of the study are:

- To implement stormwater facilities in the Study Area.
- To upgrade the effectiveness of the existing stormwater infrastructure network.
- To provide control structures against excessive sediment and floatable rubbish in watercourses.
- To construct stormwater collection and conveyance systems.
- To develop the Stormwater Asset Inventory System.

This project was proposed with the prime objective to set-up an example and showcase of the application of MSMA for urban stormwater management and flood prevention project in Malaysia, particularly in the state of Melaka. It was also aimed to study the existing hydraulic and hydrologic characteristics, as well as the water quality conditions of an urbanized drainage system subjected to flood and tidal effects. The drainage system proposed for the development area has been designed to comply with the new guidelines of Department of Irrigation and Drainage (DID), Urban Stormwater Management Manual for Malaysia or MSMA. The design system includes several components namely engineered waterway, resizing of culverts, constructed wetland and pumping station to cater for the future development discharge generated from the development area. Most of the concepts are modified from Integrated Sustainable Urban Drainage System (SUDS) options. Effects have been made to ensure no recurrence of flooding after the project is completed. Further improvement of water quality is expected with the construction of constructed wetlands.



Title: Study on River Sand Mining Capacity in Malaysia

Type: Research Contract

Funded by: Department of Irrigation and Drainage (DID)

Year: 2007-2008

Project Cost: RM 950,000.00

Executive Summary :

The present study covers three rivers i.e Sungai Muda, Sungai Langat and Sungai Kurau that have different level of sand mining activities. Sungai Muda has a long history of sand mining activity along the upper reach. Sungai Langat recently has been a major source of sand for construction with the development of Putrajaya. Fewer activities of sand mining are on-going in Sungai Kurau at the upstream of Bukit Merah wreservoir.

The objectives of the present study include the assessment of the river morphology, hydrological and sediment transport modelling and development of river register database. Field works on selected sites for the three rivers were made to assess the capacity of the river to convey both water and sediment. Data collection on bed material was made to characterize the physical characteristics of sediment responsible for sediment transport that determines the river response in terms of erosion and deposition. The three rivers clearly have the bed material size in the sand-gravel ranges based on the collected data in the present study.

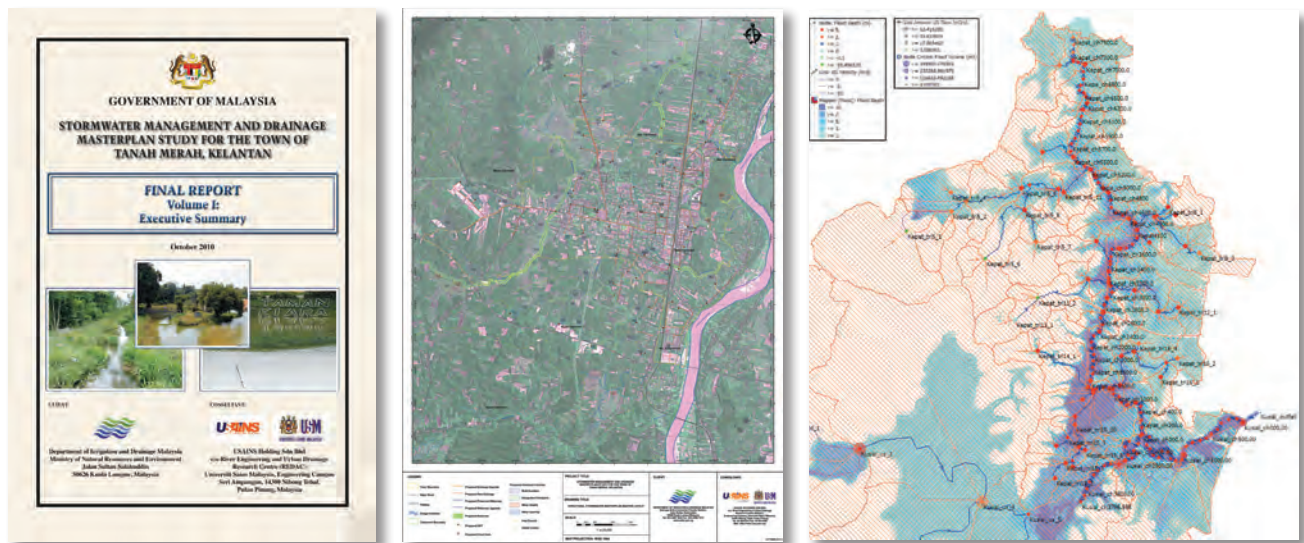
The replenishment rate as determined from the measured sediment rating curves for the three rivers show that a steeper curve is obtained for Sungai Langat as compared to Sungai Muda and Sungai Kurau. Hence, it is expected that Sungai Langat has a good replenishment rate for the purpose of sand extraction compared to Sungai Muda and Sungai Kurau. A detailed sediment transport study at six sites for each river was conducted to determine the suitability of existing sediment transport equations for use in the selected sediment transport models. It was found that Yang and Engelund-Hansen equations are able to predict the trend of sediment transport for the three rivers. Hydraulic and sediment transport modeling study were carried out to determine possible location of deposition



along the three rivers in the present study. The depth and volume of deposition will in return determine the viability of sand extraction taking into account the ability of the rivers to replenish the sediment. Three models were used for this purpose: HEC-RAS, FLUVIAL-12 and SWAT.

Proposals on the minimum level or “redline” and maximum level for sand extraction are given based on the HEC-RAS modelling results. It is proposed that the minimum depth of the excavation or redline must be at 1 m deposition above natural channel thalweg elevation while the maximum allowable mining depth is 1.5 m. The extraction is allowed for the whole active channel width after taking into consideration of the required setback to avoid bank erosion, and buffer zone encroachment. Allowing the channel wide extraction will increase the volume of the extraction for a particular site. Hence, few mining sites are allocated for each river which will minimize the disturbance to river equilibrium and environment. Based on the sedimentation trend as predicted by HEC-RAS model and after applying the 1 m redline, it can be concluded that Sungai Langat is viable for sand extraction purpose while Sungai Kurau should be prohibited from any sand extraction activity. Since Sungai Muda is being widened for flood mitigation purpose, it is recommended that deposition should be allowed to occur first after a major flood before any sand extraction activity is allowed in the 40-km lower part of the river.

Comparisons with the existing DID guidelines on sand mining were made based on the modelling results. As a result, a new guideline on river sand mining management is included in this final report that emphasizes the impacts of sand mining and several recommendations for a sustainable sand extraction, including discussions on appropriate extraction methods and sites adopted from overseas experience. Flood plain mining is also proposed as an alternative to in stream mining. Also, Geographical Information System was utilized for the study areas in the development of river register database.



Title: Stormwater Management and Drainage Master Plan Study for the Town of Tanah Merah, Kelantan

Type: Research Contract

Funded by: Department of Irrigation and Drainage (DID)

Year: 2007-2009

Project Cost: RM 990,000.00

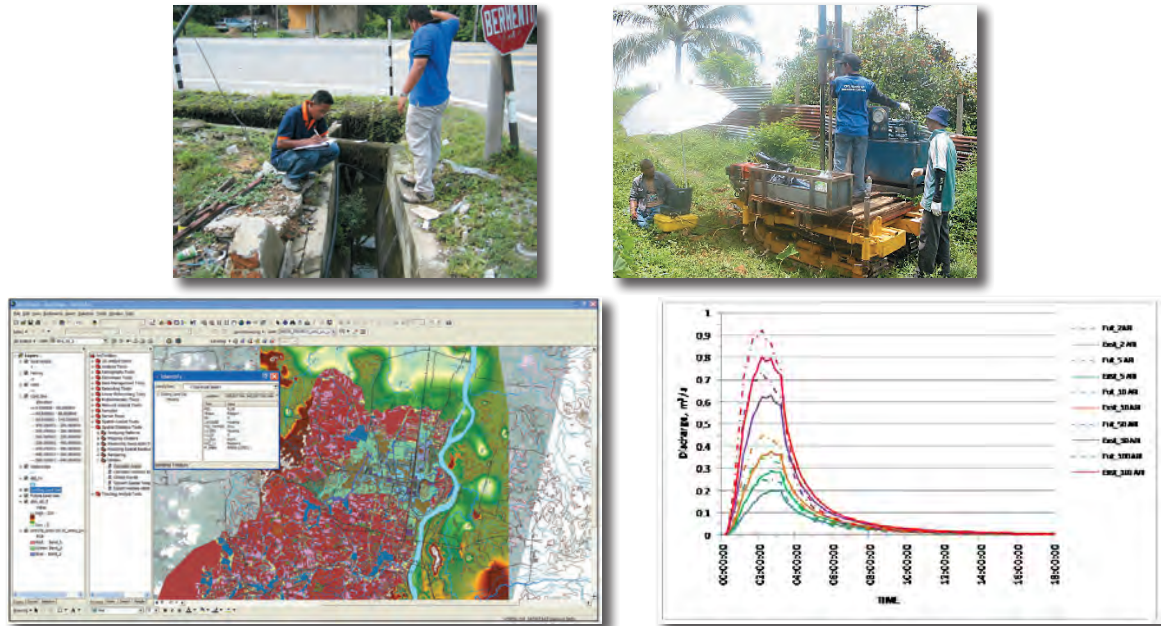
Executive Summary :

Tanah Merah town is located in District of Tanah Merah with a total catchment of 64 km². The lack of the proper drainage system has caused some areas to be flooded during intense storm. The situation has been even worst during the monsoon where the overflow from the Sungai Kelantan will backflow into the lowland areas through the several stream in Tanah Merah. A part from that, the uncontrolled physical development and human growth has cause the deterioration of water quality and loss of natural ecosystem. Therefore, a drainage and stormwater management master plan for the area of town Tanah Merah is needed to address these water-related problems and at the same time complements the development ambition of the town.

In order to achieve the objectives, analyses were carried out to investigate the severity of existing issues and potential risk in the near future. The stormwater analysis carried out includes:

- Intensity-Duration-Frequency (IDF) Curve Development
- Catchment Delineation and Hydrological Assessment
- Hydrodynamic and Flood Modelling
- Stormwater Pollutant Loading Estimation

Based on the outputs from the analyses, a comprehensive stormwater master plan was established to cover water quantity and quality aspects of stormwater management in Tanah Merah. The master plan was divided into two parts, i.e. structural and non-structural master plan. Structural master plan consists of all proposed structural stormwater

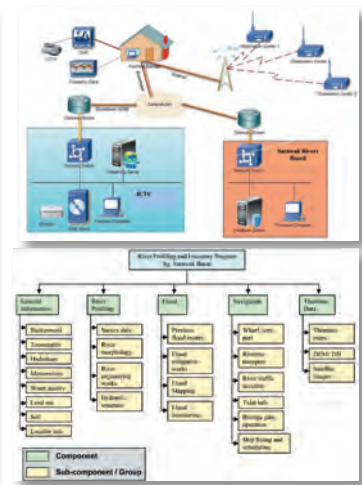


infrastructure to cater to existing and future design stormwater requirements. The proposed infrastructures include detention facilities, urban drainage, waterway upgrades, water quality facilities and outlet control gates. Non-structural master plan covers recommendations for stormwater management. This includes recommendations on land use planning (green area conservation, flood zoning, and resettlement), stormwater operation and maintenance requirements, policy on low-impact development, as well as flood response and management. The entire plan was also provided in a Geographic Information System (GIS) system together with Stormwater Asset Inventory System developed on the same platform.

The procedure of work was made up of 3 general phases, data collection, analyses, as well as design and planning. The study kicked off with data collection process to gather all relevant information and data required for analyses. Data Collection can be divided into desk work and field works. Desk work includes gathering of all published data including rainfall and stream flow records, Light Detection and Ranging (LiDAR) data, land use maps, satellite images, and soil data. Related reports and studies are also reviewed, including the existing municipal Local Plans, flood reports, and as built drawings. The study team carried out a series of field works to complement data collection. These field works provided additional data to those collected through desk work.

The project consists of five volumes as stated below:

- (a) Volume I: Executive Summary
- (b) Volume II: Introduction & Data Collection
- (c) Volume III: Hydrological & Hydraulic Analyses
- (d) Volume IV: Water Quality Assessment
- (e) Volume V: Stormwater Master Plan



Title: River Inventory and Monitoring Project (RIMP)

Type: Research Contract

Funded by: Ministry of Natural Resources and Environment (NRE)

Commissioned by: Sarawak Rivers Board (SRB)

Year: 2008-2009

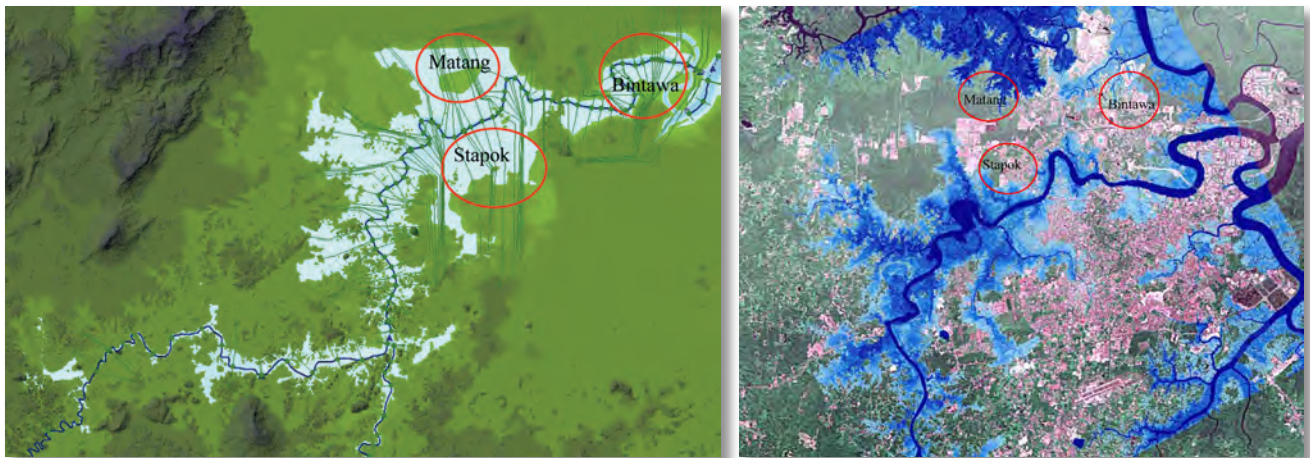
Project Cost: RM 300,000.00

Executive Summary :

Rivers in Sarawak are appreciated for their natural features and abundant resources, including sand, water, food, for transportation, fisheries resources, wildlife both in aquatic and biotic biodiversity, tourism, recreation, and increasingly, for their aesthetic value. The utilization of riverbanks and riparian areas are necessary for the economic development of the State. Along many rivers in Sarawak, industries such as timber and wood based, ship building, sand mining, food processing, agriculture products processing, river is sourced for transportation, water and other needs. However, these industries together with water from households and food outlets (e.g. markets, food centres, restaurants and etc.) generate pollutants into the river if not regulated accordingly.

With the inception of Sarawak Rivers Board (SRB) in 1993, 35 rivers have been gazetted under the Sarawak Rivers Ordinance, 1993. The ordinance and companion regulations provide the guideline for riverine transport systems, abstraction of natural resources, usage of the riparian and riverbank reserves and prevention of river pollution from various sources like vessels, ship wreckages and riverbank industries.

The River Inventory and Monitoring Program (RIMP) that will be carried out is a depository of riverine information and a clearing house whereby the public can seek information and data on Sarawak's rivers. The River Inventory means the remuneration and monitoring of main riverine activities, river profile and morphology. The scope of the

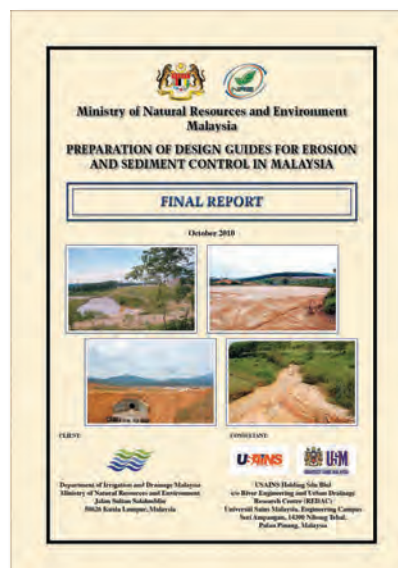
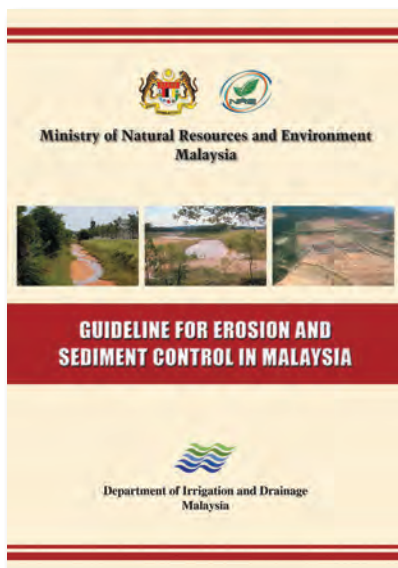


RIMP will include the set-up of a River Information Centre whereby the programme will be developed and linked into various systems such as continuous flood warning and telemetry system, river hydrology and morphology, water quality surveillance system, models of river Improvement projects and river basin management and riparian auditing proposal.

A database and RIMP website for this River profiling and Inventory Program have been suggested. The database is suggested according to the project objectives and it is expandable to include a wider scope of interest in future. On the other hand, the suggested RIMP website is to provide an interface so that information stored in the database can be provided to interested parties. The website would consist of 10 components (Home, General Information, River Profiling, Flood, Navigation, GIS, Newsroom, Publications, Webcams and Contact) which provide information related to Sg. Sarawak and a number of internal/external links in which extra useful data and information can be obtained.

A Sungai Sarawak basin-wide model is developed using the InfoWorks software. Flood mapping of extreme events, like the 50-year return period flood in February 2003, and 100-year return period floods in January 2004 and January 2009 floods have been computed to give insights to the river processes in Sungai Sarawak. The modeling results would be useful for decision support purposes in river basin management.

Based on the existing network facilities and system requirement, the most suitable Server and Network devices have been proposed to ensure sufficient data storage capacity, bandwidth for proper transmission of data and web streaming (e.g. from telemetry stations to server and from server to cloud), etc.



Title: Preparation of Design Guides for Erosion and Sediment Control in Malaysia

Type: Research Contract

Funded by: Department of Irrigation and Drainage (DID)

Year: 2008-2009

Project Cost: RM 1,000,000.00

Executive Summary :

Heavy tropical rainfall and highly erodible soils in Malaysia have caused severe erosion and subsequently sedimentation. Worse, extensive land clearing for construction has increase erosion rate, causing more sediments to end up in rivers, deteriorating water quality and destroying ecosystem. Malaysia cannot avoid from having erosion and sedimentation problems as many parts of the country are experiencing rapid development, e.g. land clearing for urban developmet, logging, and agriculture. While these activities are necessary for the development of the country, regulatory efforts to minimize erosion and sedimentation problems should not stifle economic development planned for attaining a developed country status by year 2020. Therefore, an erosion and sediment control procedure/guideline similar to that available for users in United States of America is needed for estimating general erosion rates and sediment yields specific to any particular site in the country. In principle, the procedure to be developed should be based on generally accepted equations for soil loss i.e. USLE, MUSLE, RUSLE etc. in which the variables involved are obtained through standardized charts and tables (e.g. erosivity chart based on rainfall characteristics, tables of erodibility based on local soil characteristics, tables of slope length and gradient, tables of land use practices or 'C' factor, tables of management practices or 'P' factor, and etc.) for ease of use in the country. DID saw the need for a standard procedure estimate soil loss and sediment yield based on Malaysian condition. The estimation is important to provide better design for erosion and sediment control BMPs (Best Management Practice) at construction sites and to prepare the Erosion and Sediment Control Plan (ESCP). The consultant was engaged to produce a standard design guide for soil loss and sediment yield estimation, designing of BMPs and preparation of ESCP.



The objectives of the study are:

- To enable engineers and planners to have access to a single standard procedure to calculate erosion and sedimentation rates at any site in the country, primarily for the purpose of controlling erosion and sedimentation during the earthworks stage of construction.
- To enable engineers to have expertise in designing control structures like sediment traps and basins using available historical records of rainfall for Peninsular Malaysia and soil series/type data.

The main task was to produce local values for the Universal Soil Loss Equation (USLE) and Modified Soil Loss Equation (MUSLE) parameters. Rainfall Erosivity (R) factor was developed from 10-minute rainfall data covering the latest 10 years for 241 hydrological station in the Peninsular, Soil Erosivity (K) factor was determined for 72 major soil types in Malaysia, and Crops Management (C) and Support Practice (P) factors were compiled and improved from various literatures. The final output was a set of local values ready to be used for soil loss and sediment yield estimation for Malaysia.

The Consultant also reviewed the design procedure and criteria for many commonly used erosion and sediment control BMPs. The new design has a more practical approach, where unnecessary/ over stringent criteria were omitted. Finally, the design guide also prepares user for the preparation of ESCP. The legalisation requirements, contents, and procedure in preparing a comprehensive ESCP were clearly explained. Examples were provided on design of BMPs and preparation of ESCP to enhance understanding.

The project consists of two volumes as stated below:

- Guideline for Erosion and Sediment Control in Malaysia
- Final Report

Title: Flow Resistance and Discharge Estimation for Flooding Rivers

Type: e-Science Grant

Funded by: Ministry of Higher Education (MOHE)

Year: 2008-2010

Amount of Grant: RM 220,000.00

Executive Summary :

In analysing flow through river channels, one of the most common tasks of a river engineer is to make estimates of discharge based on an estimated, recorded or simulated water level. This is very important not only to ensure sufficient water supply and waste disposal etc. During low flow, but also for practical purposes such as flood forecasting and flood mitigation during overbank flow or extreme water level. For inbank flow, the theoretical determination of the state-discharge relationship at given cross-section of a river is a straight forward issue. It is sufficient, in general, to use the overall hydraulic radius as the parameter, which characterizes the properties of the cross section. It is then possible to calculate the discharge through the channel from one of a range of well-known uniform flow formulas (such as Manning or Darcy-Weisbach) in term of the channel roughness, slope and depth.

However, once the river is in flood and flowing out-of-bank, it becomes much more difficult due to the complex 3D turbulent structure and interactions existed at the interface region between main channel and flood plain. These interactions, i.e. momentum transfer and apparent shear can significantly reduce the discharge capacity of a river. Due to this reason, traditional flow equations and methods in overbank flow discharge estimation were found to be not very accurate, and may lead to serious over-or underestimation of discharge capacity. This has become the subject of considerable researches in the past 30 years focusing on various aspect of compound channel such as flow distribution, stage discharge relationship, surface roughness, apparent shear, discharge estimation, and etc. Various methods as well as empirical formulas have also been proposed for overbank flow calculation. Unfortunately, none yet commands wide spread acceptance. The main reason for this is that most of the previous researches are based on small, and some in large-scale laboratory investigations, with certain idealized conditions, i.e. uniform cross-section, flood plain topography, surface roughness and bed slope etc. Under such conditions, the equations derived will not be generally applicable. In this case, field study of flooding river channels would be the best way to further understanding of overbank flow, as well as evolving accurate methods of discharge prediction. Unfortunately, fieldwork is rare, partly because compound channel flow conditions occur typically under flood conditions when acquisition of data is difficult and sometimes dangerous. Therefore, this study is proposed to study the hydraulic characteristic and to derive a reliable method for discharge estimation of flooding river.

The stage-discharge relationship (H vs. Q) for overbank flow is of great practical importance, as it not only links discharge with water level in flood routing models, but also it is frequently used to obtain estimated of flood discharges at extreme water level for practical purposes. Therefore, this study has been proposed for river engineers to estimate more accurately the discharge in flooded natural rivers, and hence provides the engineering community with a reliable method for flood forecasting and flood mitigation projects. At completion, this study can also be extended to developed a hydraulic or hydrodynamic model for inbank and overbank flow of open channels. The development of such model which account for the interaction of main channel and flood plain flow, and based on extensive laboratory, as well as field is very important for open channel hydraulic as well as for practical purposed in future.



Title: Detailed Design of Stormwater Management Facilities for Kulim High-Tech Industrial Park, Kedah

Type: Research Contract

Client: Abadini Integras Engineers Sdn. Bhd

Funded by: Department of Irrigation and Drainage (DID)

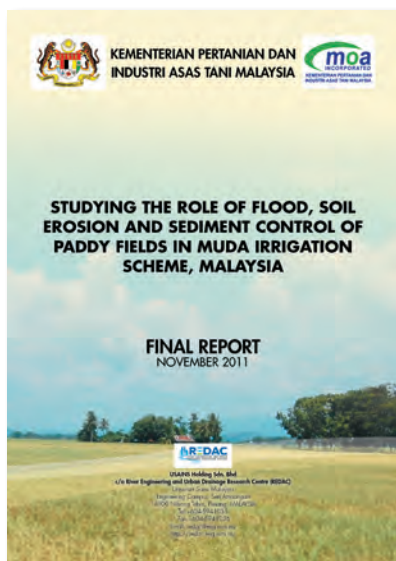
Year: 2009-2010

Project Cost: RM 250,000.00

Executive Summary :

The Kulim Hi-Tech Park (KHTP), which was officially opened in 1996, is the first high technology industrial park in Malaysia. The Park is located at Kulim, Kedah Darul Aman, covering a land area of approximately 1,700 hectares (approximately 4,000 acres). It was identified as the main industrial hub of the northern region, together with Bayan Lepas in Penang. Unfortunately due to rapid development, stormwater has increasingly becoming an issue with localised flash floods occurring as a result of heavy rainfall. Even worse, the excessive amount of runoff from KHTP has been adjudged to cause flooding downstream of the development by many locals. Apart from that excessive sediment due to uncontrolled land development is also an alarming environmental issue in the area. REDAC working in association with Abadini Integras Engineers Sdn Bhd was appointed on 4th Novemebr 2009, to provide consultancy services for stormwater management in Kulim High Tech Industrial Park in Kedah This 8-month study covered stormwater analyses, detailed design and production of tender drawings and documents to improve the stormwater system in KHTP.

Firstly, a hydrodynamic model (InfoWorks CS) was built and used to assess the stormwater system performance of the study area. Despite having 13 detention ponds in the study area, runoff was found to be significantly higher in existing condition compared to the pre-development state. The root was traced down to the ineffective detention control provided by the ponds. Some detention ponds provides as little as only 10% flow reduction due to oversized outlet structure, on-line configuration and excessive sediment deposition. A plan was drew up to retrofit all these underperform ponds by redesigning the outlet structure, desilting and re-profiling the ponds. Water quality control elements were also introduced to the site by incorporating water quality capture volume, aquabench (aquatic/ wetland plant species along water fringe) and gross pollutant traps. Again, hydrodynamic modelling was used to verify and gauge the performance of the retrofitted ponds. Overall catchment runoff control was found to achieve a better level, with most ponds providing at least 40% of runoff reduction under various design rainfall. The proposed upgrades were divided into construction projects where engineering drawings and tender documents are being prepared and submitted to DID.



Title: Studying the Role of Flood, Soil Erosion and Sediment Control of Paddy Fields in Muda Irrigation Scheme, Malaysia

Type: Research Contract

Funded by: Ministry of Agriculture and Agro-based Industry, Malaysia

Year: 2009-2010

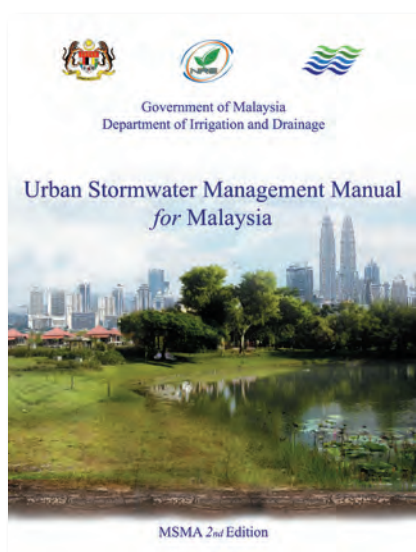
Project Cost: RM 250,000.00

Executive Summary :

Paddy fields are found majority in the Asian regions where it contributes staple food i.e. rice which are consume by almost half of the world's population in this region. Paddy fields have multifunctionalities or multiple roles (e.g. food production and security, flood control, water purification, social economic improvement, preservation of soil erosion, cultivation of ground water, habitats of aquatic animals, reduction of nitrogen content in irrigation water, climatic mitigation agro and eco-tourism and amenities, cultural and education, etc..) which are important to Malaysia as a whole. The Consultant was appointed by Ministry of Agriculture and Agro-based Industry Malaysia to conduct this study, concentrating on the capacity of paddy fields in providing flood, sedimentation and erosion control. The study was conducted in selected paddy plots in Pendang, Kedah, which is under the Muda Irrigation Scheme, operated and managed by Muda Agricultural Development Authority (MADA). Monetary assessment was later added to the study scope for the quantification of such functions in terms of monetary value.

The study kicked off by field works and site data collection including field survey, river gauging, soil tests, water quality tests, etc. The study was conducted in two scales, first the macro scale studied the flood and sediment control functions at a regional level, i.e. the contribution of collective paddy fields as a single subject of study. A micro scale study was also carried out to examine the contribution of individual paddy fields in these functions. At both scales, flood and sediment control are conducted separately. Flood control at macro scale was studied by a flood hydraulic model, examining the importance of paddy field in flood attenuation when a river overflows. The sediment control was examined by 1D sediment transport model, an extension to the developed hydraulic model to examine the capacity of paddy field in aiding sediment settlement away from flood water.

The analysis on micro scale for flood control was carried out by water budget analysis of 3 individual paddy plots to determine the relation and capacity of paddy field in regulating local hydrology and hence, prevent flood through retention of stormwater runoff. The sediment control function at micro scale was studied by monitoring the total suspended solids content in irrigation water at various part of a paddy field across a planting season. Eventually, the study found that at both macro and micro scale, paddy field play a significant role in flood and sediment control in the study area. A monetary assessment carried out using Cost Replacement Method (CRM) projected that paddy fields across the country might contribute RM 284 million and RM 7 million in flood and sediment control annually to the country.



Title:

Preparation of Urban Stormwater Management Planning and Design Standard for Malaysia and Second Edition Urban Stormwater Management Manual for Malaysia (MSMA Made Simple)

Type:

Research Contract

Client:

PWM Associates Sdn. Bhd.

Funded by:

Department of Irrigation and Drainage (DID)

Year:

2009-2010

Project Cost:

RM 250,000.00

Executive Summary :

Conventional drainage system in Malaysia, is based on the first urban drainage manual "Planning and Design Procedure No.1: Urban Drainage Design Standards and Procedure for Malaysia", which was published by DID in 1975. This manual has been used as a guideline for more than twenty-five years. However, there have been many new technological developments in urban systems, making the manual less relevant. Conventional drainage system, unfortunately has led to increase in the occurrence of flash floods. Additionally, open drainage contributes to more polluted river as there are little or no water quality treatment or control. Therefore conventional drainage is no longer an effective measure in tackling present stormwater issues. Due to this concern, Department of Irrigation and Drainage (DID) Malaysia took a proactive step by introducing a new Manual known as the Urban Storm Water Management Manual for Malaysia (Manual Saliran Mesra Alam or MSMA). From 1st January 2001 onwards all new development in Malaysia must comply with new guideline that requires the application of Best Management Practices (BMPs) to control stormwater runoff from the aspect of quantity and quality runoff to achieve zero development impact contribution. The implementation of the new manual was expected to help in preserving the natural river flow carrying capacity.

After ten years time lapse, the Department of Irrigation and Drainage decided that it is timely for the first edition to be improved. The MSMA 2nd Edition is an improved version of the 1st Edition that provides planning and design guidance to those involved in the management of stormwater. This manual has twenty (20) chapters that accompanied by two (2) annexures. The 2nd edition of the Manual was accompanied by the Malaysian Standard Code of Practice on Urban Stormwater Management, in separate publication. This code of practice will serve to enforce the design practices contained in the Manual. REDAC was invited to co-produce this new edition of MSMA. In all, REDAC was in-charge of producing 6 chapters including swale, engineering waterways, wetlands, bio-engineered channel, hydraulic structures, as well as erosion and sediment control. Annexure on plant selection for stormwater BMPs was also entrusted to REDAC. In these chapters, existing design requirements and procedures from the first edition of the manual were reviewed to identify weakness and room for improvements. By also examining overseas manual and current advances in stormwater management, the existing chapters are updated and improved accordingly. All these chapters were also provided with step-by-step calculation example to facilitate future users.



Title: Proposed Construction and Completion of Freshwater Laboratory Complex, Tasik Chini, Pekan, Pahang Darul Makmur

Type: Research Contract

Client: UKM Perunding kejuruteraan & Arkitek Sdn. Bhd.

Funded by: East Coast Economic Region Development Council (ECERDC)

Year: 2011

Project Cost: RM 15,000.00

Executive Summary :

REDAC was officially appointed as specialist consultant for stormwater management by UKM Perunding Kejuruteraan dan Arkitek Sdn Bhd, a fully owned subsidiary of Universiti Kebangsaan Malaysia, to advice on stormwater management in their proposed development of Freshwater Laboratory Complex in Tasik Chini, Pekan, Pahang. The scope of work involved designing stormwater management system in the said premise. After detailed site investigation, REDAC put forward a stormwater system which consisted of a on-site detention and a mini constructed wetlands. The unique feature of this design was the constructed wetlands, which was designed to receive both stormwater runoff and sewage treatment plant discharge. It was upon special request by the developer to safeguard the natural environment of Tasik Chini should the treatment plant malfunction.





Title: Accredited Checker on Stormwater Management for Master Plan of Proposed Township Development at Mukim Tebrau, Johor Bharu, Johor

Type: Research Contract

Funded by: Glenmarie Properties Sdn. Bhd.

Year: 2011

Project Cost: RM 25,000.00

Executive Summary :

In early 2011, Glenmarie Properties Sdn. Bhd. (GPSB), a fully own subsidiary of DRB-HICOM embarked in initiating an eco-friendly township development namely Glenmarie Heights on Lot PTD68903, PTD68905 and PTD99396, in Tebrau, Johor. This 613.25ha township was designed on the concept of connectivity at personal and virtual level, which is driven by ample amenities and sustainable development. 87% of the site is below 15° slope, hence suitable for urban development with minor earthworks. The site is presently oil palm estate, and is served by one large catchment which covers 55% of the site, along with 14 other smaller ones. This site is strategically located within near approximation with major infrastructure of the state such as highways, economic centre, universities and airport.

The main design principle, i.e. sustainability aims to develop this site via: 1) adoption of the green building indices and the use of alternative energy sources, 2) connectivity via walkway, bikeway, recreational centre and schools, 3) Safety and security through Community, Protection Through Environmental Design (CPTED). In-line with such design concept and principles, GPSB with the advice of REDAC has agreed to adopt the Bio-Ecological Drainage System (BIOECODS) in the site. REDAC was appointed as the accredited checker for stormwater master plan design during the planning stage (Approval for Planning) of this development proposal. Subsequently, approval was granted by the local authorities on September 22, 2011, and BIOECODS was agreed to be implemented throughout the site.

Title: Urban Water Cycle Processes, Management, and Societal Interactions: Crossing from Crisis to Sustainability

Type: Long Term Research Grant Scheme (LRGS)

Funded by: Ministry of Higher Education (MOHE)

Year: 2011-2014

Amount of Grant: RM 6,000,000.00

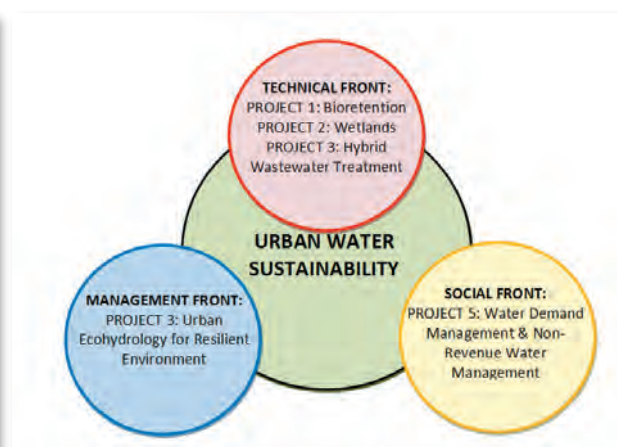
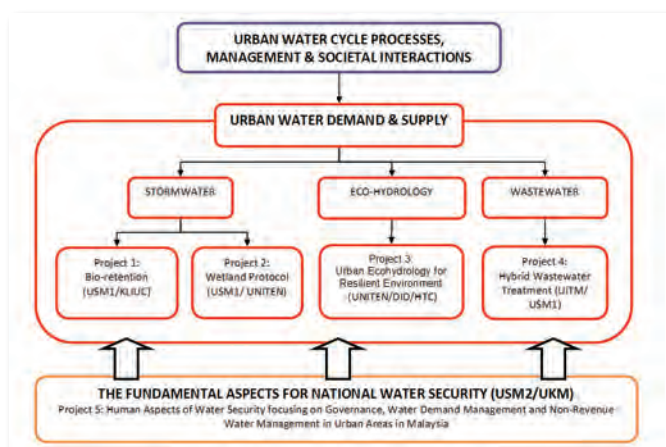
Executive Summary :

Malaysia faces serious challenges in urban water management. In terms of stormwater management, even with the introduction of MSMA in 2000 (Urban Stormwater Management Manual for Malaysia), many new technologies have yet to be studied in depth especially the interrelation between water quantity and quality. Water pollution originates from many human-induced actions such as effluents from industrial wastewater, land use changes and urbanisation. There is an emerging trans-disciplinary approach that utilises the understanding of relationships between hydrological and biological processes to improve water quality, biodiversity and sustainable development at the catchment scale. The approach implementation is based upon restoration and optimization of the ecosystem. This approach is based on three fundamental, i.e., synergising catchment water cycle and dynamic of its biotic component, harmonizing existing and planned hydro-technical solutions with ecological biotechnologies, and integrating complementary synergistic measures of all scales. Moreover, stormwater runoff is seen as a potentially valuable water resource (and not as a waste product) that requires sustainable management. This philosophy is in contrast to the traditional management of stormwater further downstream in the catchment; e.g. construction of dams within river valleys for flood control purposes.

Despite being touted as a “water-rich” country, the water equation in Malaysia has radically changed from one of relative abundance to one of relative scarcity. Population explosion, rapid urbanisation, agricultural expansion, industrialisation, tourism and other developments are imposing excessive demands and pressures on our water resources. At the same time, water availability is depleted by pollution. All these seriously threaten Malaysia’s water security. Traditionally, water problems in the country is tackled with the Water Supply Management (WSM) approach which is based solely on technology without addressing the human issues that are really the root causes of these water problems. Water Demand Management (WDM) has been shown to be highly effective in many countries and Malaysia can, and must adopt WDM. Even a small 10 % of water savings can effectively reduce pressures on our water systems and defer construction of new water infrastructures, thereby saving the country CAPEX. This is the rationale for embarking on the study of urban WDM vis-à-vis WSM.

The proposed programme puts forward the concept of sustainability in urban water management. The aim is to tackle urban water issues in a holistic manner by focusing on the critical issues related to providing an integrated solution framework so that water remains as a renewable and accessible resource not only for current population, but also for the future generations. This proposed programme brings together a collaborating group of experts and researchers with proven track records from major institutions of higher learning. The programme consists of 5 research projects that tackles specific problems/ challenges in the supply and demand of water in urban environment from all fronts.

On the technical front, the program introduces 3 research projects to tackle the water shortage and pollution issue through fundamental research in stormwater bioretention (Project 1) and wetland (Project 2) facilities, as well as wastewater treatment technologies (Project 4). There are many benefits in the application of bioretention and constructed wetlands including hydrology regulation, water treatment, and replenishment of water resource (especially critical in drier months when source of water is scarce). The present design guides are directly borrowed from overseas (not technically proven in Malaysia) resulting in poor performance and facility failure. The research will reinvestigate the fundamentals of hydrology, hydraulic, environmental science and soil-water-plant relationship, to establish design guides that are conclusive and integrated. This will create facilities that not only function to treat stormwater, but are able to provide self-sustainability, increase river base flow recharge, and subsequently



secure long term future of water supply sources. Project 4 will first investigate the characteristic of various industrial wastewater, then study how effective (or ineffective) current technology is in treating Polycyclic Aromatic Hydrocarbon (PAHs). New technologies will be innovated using hybrid of several cutting edge technology. By discharging cleaner effluents, we are able to protect environment, diversify source of water supply and cut cost of water supply treatment.

Project 3 concentrates on the Management front related to urban water issues. The solutions to most urban water issues will be sought by applying urban ecohydrology, ecohydraulics, integrated urban water management, and finally the knowledge management through an information system Decision Support System UCOREN. Environmental issues will be scientifically addressed by achieving synergy among the project researchers through joint investigations, development, implementation, and dissemination of findings and strategies, assessing impacts of and responses by scenarios of relevant drivers, quantifying cost-effectiveness of resilience measures through innovative tools, and by novel use of ecosystem properties to enhance environmental resiliency and achieve the maximum ecological potential. Extension of the urban water infrastructure to ecological measures, which is typical for the ecohydrology approach, is expected not only to improve the environmental quality but also to lower costs of mitigation and increase economic benefits to the society.

The final front of urban water issues is the social aspect, which will be tackled by Project 5. This study discard the conventional structural (supply) approach to solve critical urban water issues, and instead concentrate on studying the fundamentals and subsequently seek solutions to urban water issues through the societal or demand side of the equilibrium. This study examines: the fundamental ethics, beliefs, and practices related to water, poverty and water, gender and water, all of which is central to a deeper understanding of the causes of water problems and to discover the solutions that are deeply rooted in human society; Models of Water Governance and Models of Water Supply Management (WSM) versus Water Demand Management (WDM); Human aspects of Non-Revenue Water (NRW), Cost Recovery; Tariff Restructuring and Willingness to Pay. A triangulation strategy combining various research methods will be used.

It is hoped that through such thorough research of fundamentals from multi-discipline perspective, urban water issues can be resolved and the nation could move further forward with a secured and sustainable source and supply of clean and fresh water. REDAC are currently working with several collaborators to carry out these research, including School of Humanities (USM), Universiti Tenaga Nasional (UNITEN) and Universiti Teknologi Mara (UiTM).



Title: Development Master Plan for Bandar Baru Tunjong, Kota Bahru, Kelantan

Type: Research Contract

Funded by: Tunjong Development Corporation Sdn. Bhd.

Project Cost: Final Stage of Negotiation

REDAC was approached to conduct technical review on the proposed Development Master Plan for Bandar Baru Tunjong, Kota Bahru, Kelantan (Cadangan Pelan Induk Pembangunan Bandar Baru Tunjong, Kota Bahru, Kelantan). This development of 654 ha consists of residential, commercial, government institution, and recreational facilities. The planner had utilized existing low terrain and abundance of agricultural and natural waterway to create water features in and around the development.

Based on the provided master plan layout and drainage details, REDAC conducted review and provided constructive comments on the stormwater aspect of the development. The review was carried in reference to the Urban Stormwater Management Manual for Malaysia (MSMA) published by the Department of Irrigation and Drainage (DID). Eventually, REDAC put forward the report on the review based on the preliminary evaluations of the development. The report was divided into two parts. First, REDAC reviewed on the concept of the development based on the importance of stormwater in terms of hydrology, hydraulic, water quality and environment. The second part of the review looked into the technicality part of the design based on MSMA. As a result from the review, it was found that there were several critical aspects being overlooked by the planner. Subsequently, the plan was rejected by the Client on the advice of REDAC. Presently, REDAC continues to advise the Client and the planner on the stormwater management planning in this development.

5.0



POST GRADUATE PROGRAMME

5.1 RESEARCH PROGRAMME

REDAC offers post-graduate programmes encompassing several areas pertaining to river management at the Master of Science or Doctor of Philosophy levels. These areas are River Management, Urban Drainage Management, Hydroinformatics and Environmental Hydraulic Management. This programme is open to all Students of USM or other universities, who are qualified to pursue their graduate studies through research mode.

The subtopics for each area offered are described as follows:

- i. River Management
River Morphology, Sediment Transport, Stream Conservation & Restoration, Floodplain Management, Stream Bank Control Using Bio-engineering, Riparian Vegetation Management, Biological Impacts of River Canalization, River Modeling, Integrated River Basin Management.
- ii. Urban Drainage Management
Runoff Quantity Control (Constructed Detention/Retention), Source Control BMPs, Treatment Control BMPs (Gross Pollutant Trap, Constructed Ponds & Wetlands), Subsoil Drainage, Storm Water Modeling, Stochastic Modeling, Integrated Storm Water Management, Bio-Ecological Drainage System (BIOECODS).
- iii. Hydro informatics
Flood Risk Mapping Using GIS, Infiltration Mapping Using GIS, Integrated River Management Decision Support System.
- iv. Environmental Hydraulics Management
Environmental Management Plan (EMP), Erosion Sediment Control Plan (ESCP), Surface Water Quality Modeling, Groundwater Quality Modeling.



5.2 POST-GRADUATE PROGRAMME

PhD Student:

Shanker Kumar a/I Sinnakaudan

Supervisor

Prof. Dr. Aminuddin Ab Ghani;

Assoc. Prof. Dr. Mohd Sanusi S. Ahamad

Title

Sediment Transport Modeling and Flood Risk Mapping in Geographic Information System

Completion Year: 2003

Abstract

Most computer models used in the flood risk analysis of rivers have inadequate functions in its spatial analytical capabilities and without sediment transport simulation capacity or suitable equations to represent correctly in-situ hydraulic processes. As a result, the current research presents the development of a new total bed material load equation using multiple linear regression analyses that is applicable for rivers in Malaysia. It was developed and embedded as a modified version of HEC-6 model and named SEDFlood model. The model is best suited for rivers having uniform sediment size distribution with a d_{50} value within the range 0.37 mm and 4.0 mm and performs better than the commonly used Yang, Graf and Ackers-White total bed material load equations. A user-friendly, menu-driven GUI for two and three-dimensional (2D & 3D) digital floodplain delineation was developed through ArcView GIS and SEDFlood tight coupling procedure. It is capable to produce quick analysis (snapshots) at any desired discharge time steps in flood risk mapping procedure. Field measurements were carried out to validate the hydraulic setting and the accuracy of model outputs. The feasibility of simulating a flood event along a river channel and floodplain was tested for Pari River catchment's area located in Ipoh, Malaysia. Flood risk analysis were conducted for the design flood events for 10, 50, 100-year Average Recurrence Interval (ARI). The design rainfall duration of 30, 60 and 120 minutes for the present and future land use conditions (year 2020) were considered in the simulation scenarios. The result of this research indicates that GIS is an effective environment for floodplain analysis and its integration with hydraulic model is not only feasible but also mutually beneficial for both GIS users and hydraulic modelers.

PhD Student: Junaidah Ariffin

Supervisor

Prof. Dr. Aminuddin Ab Ghani;
Prof. Dr. Nor Azazi Zakaria;
Assoc. Prof. Ahmad Shukri Yahaya

Title

Development of Sediment Transport Models for Selected Rivers in Malaysia Using Regression Analysis and Artificial Neural Network

Completion Year: 2004

Abstract

Problems associated with sediments have become major issues for years as they affects not only the morphology of the rivers but also the cause of flooding in several areas. Knowledge on sediment prediction is important in solving river engineering problems. In lieu of this, a study on the transport of sediments in natural rivers was conducted to observe both the bed sediment load and suspended sediment load with flow. The objective is to develop a sediment transport equation using hydraulic and sediment data extracted from 12 rivers. A total of 346 data were used in the analysis and validation works. Initially an attempt was made to evaluate the nine most commonly used equations. However, these equations failed to predict sediment transport to a desired accuracy. The poor performance resulted from the difference in sediment availability from the source, composition of sediments and river configurations. Some of the equations were physically based and derived using flume data. Naturally the conditions in the laboratory are not the same as in natural rivers. Thus, a new sediment transport equation is necessary for Malaysian rivers. Three statistical techniques namely the multiple linear regression, robust regression and artificial neural network were used to determine the functional relationship between the sediment discharge variables. Subsequently a total of 71 equations were derived. Analysis showed that the proposed equation derived using multiple linear regressions gave the best prediction with an overall accuracy of 67.35%. Thus the proposed regression equation for Malaysian rivers under the flow range and sediment properties can be defined as a function of relative roughness on the bed, ratio of shear velocity and fall velocity, Froude Number and the ratio of shear velocity and average velocity. Examples of stable channel design using the proposed equations are also given.





PhD Student: Lariyah Mohd Sidek

Supervisor

Prof. Dr. Engr Kaoru Takara
Prof. Dr. Aminuddin Ab Ghani
Prof. Dr. Hj. Mohd Nor Desa

Title

Bio-Ecological Drainage System (BIOECODS) for Effective Stormwater Control in the Tropics

Completion Year: 2005

Abstract

This thesis attempts to explore alternative solutions to the conventional drainage system which has now been realized that the drastic discharge of rainwater resulted in significant ecological damage. The detrimental effects mainly concern the reduction in the natural ground water recharge, the increase in flood discharge and the considerable pollution of surface water. Since these disadvantages resulted in high costs for subsequent remedial measures (flood control, etc) widely applicable alternatives were needed.

This thesis outlines the national approach to stormwater management in Malaysia, and evolving implementation practices by State and Local government authorities. In response to the needs for paradigm shift the way the stormwater is managed, the Malaysian Government has introduced a new approach of planning and design of urban areas through the New Stormwater Management Manual for Malaysia (MSMA) that offers a sustainable solution for integrating the land development and urban water cycle. The research focused on new concepts for the urban stormwater runoff and the water quality management based on integrated stormwater solutions. The USM Engineering campus is a pilot project for urban stormwater management strategy as an example of an ecologically sustainable development based approach to urban stormwater management. The concept is based on open and natural drainage systems integrated into multipurpose open space/environmental corridors or greenways, is the most promising approach in newly developing or urbanizing areas.

This thesis aims to introduce such an alternative - the "Principle of Control-at-Source" based on Storage-Oriented Approach. With respect to its technical implementation the term "Bio-Ecological Drainage Systems"), further in this text referred to BIOECODS) has prevailed. The BIOECODS combines four engineering techniques to manage stormwater based on "Control-at-Source" approach namely infiltration, storage, conveyance and treatment by integrating the drainage components (i.e. ecological swales, on-line sub-surface detentions, and dry ponds) with the ecological pond components (i.e. detention pond, constructed wetland, wading stream and recreational pond). In combination, this approach increases runoff lags time, increase opportunities for pollutant removal through settling and bio-filtration, and reduce the rate and volume of runoff through enhanced infiltration opportunities. With this new approach, the main bulk of stormwater is collected and stored at its source to allow natural cleaning to occur prior to infiltration or controlled release to watercourses to reduce impact on river capacity.

Bio-Ecological Drainage System (BIOECODS) is an example of an innovative sustainable urban drainage system consists of different stormwater drainage facilities suggested in MSMA that designed to restore the natural environment implemented at USM's Engineering Campus with the following objectives:

- Promotion of stormwater infiltration from impermeable areas (e.g. roof tops, car parks) by using bio-ecological swales
- Gradual release of stormwater through the use of bio-ecological swales, on-line underground bio-ecological detention storages and bio-ecological dry ponds
- Treatment of stormwater quality using treatment train concept by utilising bio-ecological swales and bio-ecological ponds (e.g. wet pond, wetland) as the storm water moves downstream.

This thesis first introduces the survey study on the current stormwater management practices in Malaysia. The preliminary study has shown that the Urban Stormwater Management Manual (MSMA) was written based on overseas experience with limited local data and information of local conditions. In order to understand the current stormwater management practices in Malaysia and the deficiencies and errors in the MSMA manual, the surveys were conducted in order to evaluate the status of the stormwater management practices in Malaysia such as issues on public awareness, design aspect, best tools of stormwater facilities, errors or deficiencies in MSMA manual, cost, maintenance and public acceptance towards the MSMA manual.

In order to understand the behaviour of on-site source control facilities, this thesis also investigated the small scale pilot project of subsurface infiltration and storage tank system (on-site retention/detention system) to control stormwater quantity in Engineering Campus Universiti Sains Malaysia, Tronoh, Perak. The objective of the project is to implement the on-site source control and distributed storage systems to attenuate the peak flood hydrograph and volume by using three different infiltration and storage techniques namely module infiltration system, loose rock infiltration system and module storage tank system. The results were used as basis for the development of full scale pilot project of BIOECODS.

The basic principles of the design and concept of BIOECODS are discussed in detail in this thesis followed by a description of technical and constructions of BIOECODS. The objectives of the study for BIOECODS are focused on the hydraulic performance, water quality treatment train performance and the economic evaluation. In order to study the effectiveness of the full scale pilot project BIOECODS in treating the stormwater runoff, a storm water quality monitoring programme is being carried out by two methods namely grab sampling and automatic sampling method at ten sampling stations along ecological swales and at eight sampling stations along ECOPOND. The hydraulic performance of the BIOECODS system is focused on the ecological swale, dry pond and ecological pond. The effectiveness of an ecological swale is considered from the aspect of quantity control in terms of peak flow attenuation. The operational functional of a dry pond is calculated in terms of its capability to retain and drain the storm water. Dry pond is an off-line storage designed with the function to reduce peak discharge at the downstream by infiltrating through the layer of topsoil and river sand into the storage module underneath before flowing to the downstream of the sub-surface module of the swale. In addition, the Storm Water Management Model (XP-SWMM) is used to model and simulate the hydrologic and hydraulic performance of BIOECODS. Finally, the economic aspect of BIOECODS is studied by developing a simple method to conduct life cycle cost (LCC) analysis of BIOECODS. The simple LCC method was applied to a pilot project of USM Engineering Campus and it is found that the BIOECODS method has a lower capital cost but due to higher maintenance cost, its life cycle cost is little higher than the traditional method. However, the study has shown that the little increase in life cycle cost associated with the BIOECODS method can be balanced with the long term benefits gained from this innovative urban drainage system as part of sustainable approach in the new development area.

Overall, the outputs of this thesis give a useful insight into the status of stormwater management practices and effectiveness in Malaysia that will help with the development and delivery of new updated version of MSMA manual. Moreover, the results obtained from small scale project for on-site retention/detention systems and full scale project for BIOECODS have confirmed the good performance of the systems in attenuating the peak runoff and treating the stormwater runoff. Finally, the results can be used to support the MSMA manual with a local data for the updated version of MSMA manual in the next five years.

Effective new concept of Stormwater Management Manual for Malaysia (MSMA) is not easy to achieve and requires an innovative approach and commitments from all the key stakeholders. Furthermore, developing technologies or new approaches of stormwater management to improve the environmental protection and enhancement will always lead to temporary spatial and procedural inconsistencies. These issues can be seen as areas for development: addressing them allows the overall approach to be improved. It is only by methodically evaluating progress and barriers, and strengths and weaknesses at the grass roots level that these valuable lessons can be learnt and shared for the benefits of the nation.

PhD Student: Mohd Farid Ahmad

Supervisor

Prof. Dr. Nor Azazi Zakaria

Assoc. Prof. Ir. Dr. Mohamad Razip Selamat

Title

Comparative Performance of Loose Sandy Soils Improved by Deep Compaction Techniques

Completion Year: 2005

Abstract

The objective of the study were determine the effect of fine content on the improvement of cohesionless loose sandy soils, to evaluate and compare the effectiveness of the dynamic compaction and vibro-compaction techniques, to provide suitable semi empirical models on improvement and finally to propose a suitable comparative performance chart that can help select the technique that provided higher improvement. The research was conducted at study site in Kerteh, Terengganu. Based on improvements made, it was found that the increase in soil resistances after completion of treatment differs between the two techniques. Extensive soil samples were then collected using specially fabricated sampling tube, and wet grading analyses on the soils were performed in the laboratory to determine the difference in fine content. Models were then developed to determine the relations between improvements against soil resistance. Cubic semi-empirical models were found to be the best models for both dynamic compaction and vibro-compaction. The models allowed direct usage of the cone resistance to evaluate the performance of the deep compaction technique incorporating the effect of fine content. The models were then used to produce a suitable comparison chart that can assist engineers in designing the compaction techniques.



PhD Student: Rabie A A Hussein

Supervisor

Prof. Dr. Aminuddin Ab Ghani;
Prof. Dr. Nor Azazi Zakaria;
Assoc. Prof. Dr. Mohd Sanusi S. Ahamad

Title

Flood Hazard and Risk Assessment through incorporating GIS with Hydrodynamic Modelling: Case Study of Muda River

Completion Year: 2009

Abstract

Muda River has been for many years experiencing seasonal floods and causing serious damage and economical loss to human settlements and property in the Muda basin. The 2003 flood was the most devastating event throughout the history of the river. The geomorphological changes, flood behavior and impacts of the Muda River have been investigated in this study using integration of specialized software packages and computer modeling techniques to envisage the consequent changes projected on the river, and assisting in predicting and communicating the flooding risk. Ground surface roughness was delineated through several field visits to the study area. This ground roughness acts as a significant input data for hydraulic modeling purpose. The results of one-dimensional hydrodynamic modeling showed a wide spatial extension of flooding inundation in the vicinity of the floodplain, and indicated damage severity on households and agricultural land use features located in these highly inundated areas. Hazard assessment and risk analysis on these two land use types revealed that the economical damage of the 2003 flood (RM 27.6 million) was five times than that of the last flood (1982) in a 20-year-period (RM 3.87 million). This enormous loss can be attributed to the dramatic changes imposed on the riverine system by much historical and contemporary unsustainable human exploitation of the Muda basin land assets, increasing its vulnerability to erosion hazards and decreased ground surface roughness. The 100-year flood event model was also reconstructed in order to investigate the effectiveness of the proposed bund in controlling the increase in water depth during extreme flooding conditions. The modeling indicated that the proposed bund has enough capacity to contain safely the flood water, with an additional capacity of containing extra 1.5 m of flooding water without exceeding the breaching point. The modeling result also suggests the effectiveness of the proposed bund structure in reducing the flooding risk, protecting thereby the human activities in the floodplain. On the long run, the engineered river may experience localized geomorphic adjustments without initiating flood hazard; but under futuristic extensive and extraordinary channel instabilities, geomorphic adjustments may become magnified, initiating thereby flooding event in the study area. The computer modeling performed in this study improved the understanding of the long-term behavior of Muda River and its flooding behavior.



MSc. Student: Ahmeda M. Saleem

Supervisor

Prof. Dr. Aminuddin Ab Ghani

Assoc. Prof. Dr. Rozi Abdullah

Title

Incipient Motion Over Loose Deposited Beds in A Rigid Rectangular Channel

Completion Year: 1998

Abstract

The presence of sediment deposits in a drainage system or rigid channels as monsoon drains could produce flash flood. The ability of the drainage system to erode sediment deposit will allow the system to carry the designed discharge.

The aims of the present study are to gain an improved understanding of the incipient motion processes in urban drains and to provide improved incipient motion relationships. This is achieved by investigating the important parameters governing the incipient motion of particles for several bed thicknesses.

In the first part of the study, the characteristics of flow in a rectangular cross section channel with different water flow depths and various slopes were studied. A series of incipient motion experiments were then carried out in a rectangular channel 300 mm wide and 10 m long. Four different bed thicknesses (t_b) were used namely d_{50} , 5 mm, 10 mm, and 24 mm utilizing sediment with size between 0.55 mm and 4.78 mm. The sediments were collected from existing drains in Ipoh City and Batu Gajah Town.

The present data were utilized to appraise the existing incipient motion criteria for rigid channels. The results show that the existing equations are valid only for the case of bed having thickness equals sediment size (d_{50}) only. New incipient motion criteria applicable for various bed thicknesses were then developed for 1% & 5% (h is the channel depth = 450 mm). These new equations could be used to design new drainage systems with the ability to erode deposited sediment.



MSc. Student: Zorkeflee Abu Hasan

Supervisor

Prof. Dr. Aminuddin Ab Ghani
Assoc. Prof. Dr. Rozi Abdullah

Title

Evaluation of Scour and Deposition in Malaysian Rivers Undergoing Training Works: Case Studies of Pari and Kerayong Rivers

Completion Year: 1998

Abstract

Numerous flood mitigation projects are being implemented throughout the country especially in urban areas. The occurrence of floods after the project completions shows the project completions shows the existence of damages to the rigid bank walls and serious problems of erosion and deposition.

Referring to the above problem, two completed flood mitigation projects, namely, Pari River Flood Mitigation Project Phase 2, Ipoh and Kerayong River Flood Mitigation Project Phase 4, Kuala Lumpur were chosen as case studies. The aims of the study are to evaluate the capacity of newly improved channels for both projects in accommodating the designed flood discharge and the stability of the bank protection structures taking into account effects of erosion and deposition using two mathematical models, namely, FLUVAL – 12 ("Mathematical Model for Erodible Channel") and HEC – 6 ("Scour and Deposition in Rivers and Reservoir"). This research also emphasis sediment transport in alluvial river since it can be considered as a new subject in this country.

Result of this study on sediment transport in several rivers in Kinta District show that the existence of relationships between bed load and discharge, total bed material load and discharge, and between bed load and bed material. Graf's (1968) and Yang's (1972) sediment transport equations are found to be suitable for predict the sediment transport in all the rivers studied. Calibration results for Pari River show that FLUVAL – 12 using Graf's give the closest resemblance to measured flood levels, flow rating curve at Manjoi Bridge and the location of damaged rigid bank walls. Calibration results using HEC – 6 shows that this model can be used for estimating the channel capacity but not suitable for analyzing the stability of the bank protection structures at Pari River. Simulation result of Kerayong River shows that Yang's sediment transport produces a better result compared to Graf's equation (which is more suitable for Pari River). This indicates that different rivers may behave differently. Hence the problems pertaining to each river should be treated individually.



MSc. Student: Nasehir Khan E.M Yahaya

Supervisors

Prof. Dr. Aminuddin Ab Ghani
Assoc. Prof. Dr. Rozi Abdullah

Title

Development of Total Bed Material Transport Rating Curves for Rivers in Malaysia: Case Studies of Pari River and Kerayong River and Kulim River

Completion Year: 1999

Abstract

Development, which takes place in river catchment areas, will result in discharge and bed erosion increment or scouring and deposition. The matter stated above will result in the unstability in the river channel. When this happens, there will be failures to the riverbank or in the river protection structure and reduce the channel capacity to flow the flood to downstream. Therefore, it is necessary to predict the river channel stability that will happen due to the existing development or the one which will take place in the future in a river catchment area.

This study covers three rivers, which are Pari River in Ipoh, Perak, Kerayong River in Kuala Lumpur and Kulim River in Kedah. This study involves the collection of hydrological data such as rainfall data, river stage data, the discharge and also data related to erosion and deposition like the river bed sediment load, suspended load and river bed material. Observation was also conducted to identify the changes of the riverbed in a few locations of these rivers. The data collected were analyzed to assess the sediment transport equation in order to predict the sediment rate that is very close with the observed sediment rate.

The new equation for sediment transportation for the rivers in Malaysia is also formed based on the observed data. It was found that the Yang equation is the best followed by the Graf equation. Base on the equations that are stated above sediment transport rating curve can be developed in any locations of a river. The information of the sediment transport rating curve together with the sediment information connected to the design of hydrograph information generated from RORB model can be used in sediment transport models such as HEC-6 and Fluvial-12 to predict the river channel stability due to the existing development or in the future in a river catchment area. Hence, engineers can take some possible early actions to protect the riverbanks or the river protection structures from any failures. The maintenance works of the river could be run efficiently with the minimum cost.



MSc. Student: Noor Azman Ibrahim

Supervisors

Prof. Dr. Aminuddin Ab Ghani

Prof. Dr. Nor Azazi Zakaria

Assoc. Prof. Ahmad Shukri Yahaya

Title

Evaluation and Development of Sediment Transport Equations for Kinta River, Kulim River and Kerayong River Basins

Completion Year: 2002

Abstract

Sediment transport in rivers involves complex interaction between numerous inter-related variables. Empirical methods emphasize only a certain number of parameters that are considered to be more relevant by their developers. In the past, a large number of sediment transport equations were developed using data derived from laboratory experiments with shallow flows.

In this study, four commonly used bed load equations namely Einstein, Einstein-Brown, Meyer-Peter-Muller and Shields and four total bed-material load equations, Ackers-White, Engelund-Hansen, Graf and Yang were used to evaluate the sediment transport rates for Malaysian rivers. A total of 108 sets of data were collected from the Pari, Kinta and Raia Rivers in Ipoh, Perak, the Kerayong River in Kuala Lumpur and Kulim River in Kulim, Kedah. These data were analysed and evaluated using the above-mentioned eight equations. Comparison of discrepancy ratios i.e. the ratio of computed transport rate over measured values, were done and the results showed that the Ackers-White equation yielded the highest evaluation with 76 % followed by the Yang, Graf and Engelund-Hansen equation at 50 %, 48 % and 46 % respectively.

Subsequently, four sediment transport equations for Malaysian rivers, namely equations 6.13b, 6.14a, 6.16f and 6.17f were developed using computer software, Statistical Products and Services Solutions (SPSS). The same sets of data were then used for evaluation of the equations developed. The result shows highest percentage of discrepancy ratio is obtained for Raia River at 71 %, 67 % and 76 % using equations 6.13b, 6.14a and 6.17 f respectively. For equation 6.16f, the Pari River yielded the highest at 57 %.

Overall, the Raia River showed outstanding results using the equations developed. This augurs well for further research on sediment transport in Malaysian rivers.



MSc. Student: Abd. Kadir Nik Abdullah

Supervisor

Prof. Dr. Nor Azazi Zakaria
Dr. Dini Ramya Hassan Basri

Title

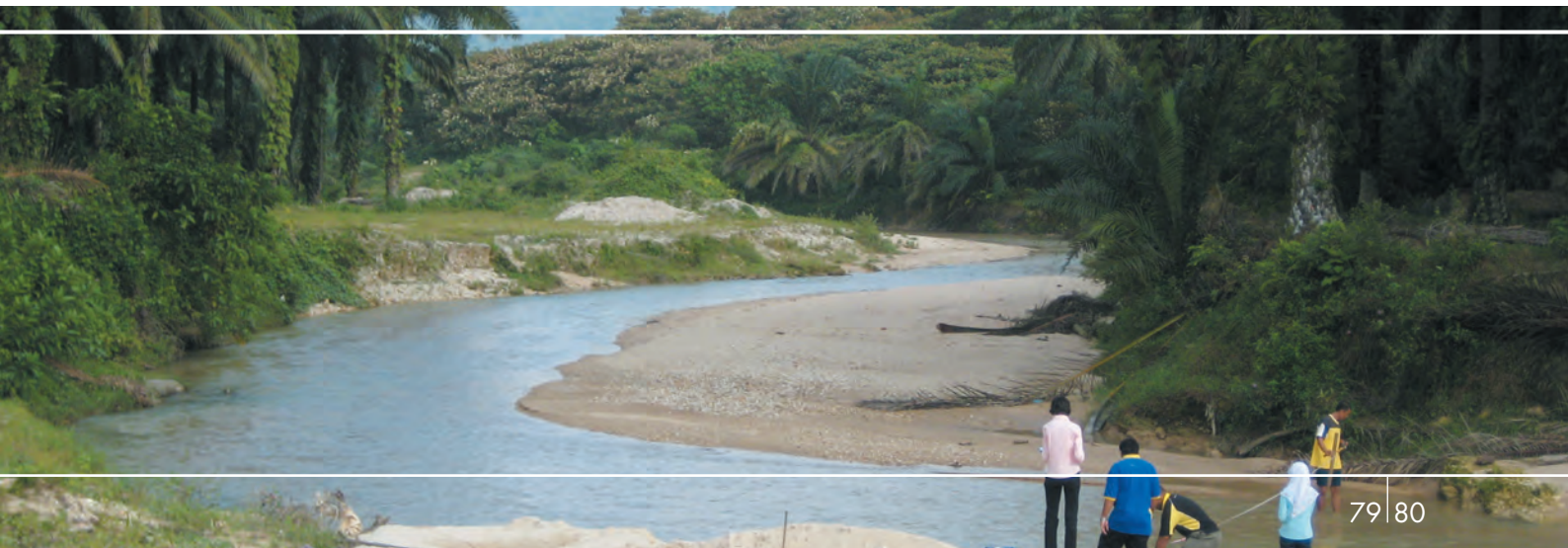
Site Suitability for Solid Waste Disposal by Natural Attenuation Near Coastal Area

Completion Year: 2002

Abstract

Solid waste disposal using land filling method is becoming increasingly popular all over the world. It consists of two design concepts, namely natural attenuation and containment sites. The natural attenuation concept uses soil as liners. The soil properties of liners such as permeability, liquid limit and plastic index, percentage of clay content, particle size and soil particles distributions may influence the concentration and movement of leachate into the surrounding ground water. Besides the above-mentioned properties, some other possible aspects influencing the concentration of leachate are the movement of molecules into porous materials and the interface action between polluted ground water and salt water from the sea. Besides the value of soil permeability coefficient may change due to settlement and consolidation of solid waste.

This study is to investigate the effectiveness of soil functioning as liners in natural attenuation concept. The purpose is to determine the suitability of soil properties near coastal areas. The research done covers the soil parameters, permeability coefficient values, and the effect to the concentration of leachate. Marine soil properties near coastal areas can control the leachate concentration besides settlement and consolidation effects. The research shows that the soil characteristic has fulfilled the specification made for soil that functions as liners. This shows that marine soil can be used as liners for land filling. The research is carried out at the landfill area situated at Teluk Kitang, Kota Bharu, Kelantan. The finding of this research indicates the suitability of marine soil as liners. It is recommended to further the studies in other marine located in other parts of Peninsular Malaysia.





MSc. Student: Yong Rashidah Mat Tuselim @ Selamat

Supervisor

Prof. Dr. Nor Azazi Zakaria

Dr. Dini Ramya Hassan Basri

Title

A Study on the Effectiveness of Using a Bio-Physical Pilot Plan Rotating Biological Contractor-Sedimentation as a Secondary Treatment of Leachate

Completion Year: 2002

Abstract

The main objective of this study is to carry out an investigation and evaluation on the effectiveness of using a bio-physical unit treatment, which is a compacted unit combining an aerobic biological system; a rotating biological contractor (RBS) and physical system; a sedimentation tank, as a secondary treatment of leachate from Pulau Burong Landfill in Seberang Perai. The influent leachate to the unit is supplied from an aerated lagoon which is the landfill's primary treatment of which effluent qualities do not comply to Standard B effluent parameter limits stipulated by the Environmental Quality Regulation (Sewage and Industrial Effluents), 1979 in the third schedule of the Environmental Quality Act, 1974. This pilot scale study is conducted at Pulau Burong Landfill site in order to obtain operating data under real field conditions.

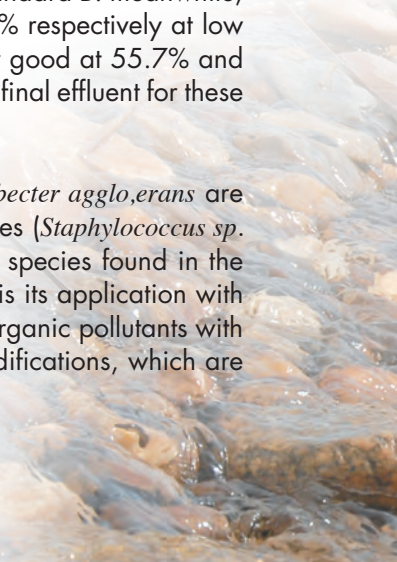
Evaluation of the Unit's effectiveness is done by monitoring treatment efficiencies in the (i) unit as a whole system and (ii) and its' individual system which is the biological –RBS system and the physical-sedimentation system. Treatment efficiencies are expressed in the form of substrate removal for parameters COD, NH₃-N, SS, VSS and metals removal for parameters Fe, Mn, Ca, Mg and Ni. Charges in pH and alkalinity of the effluent are also monitored. Investigation is also carried out to identify the effect of loading rates on the unit's treatment efficiencies; while in the biological RBC system, the relationship between loading rates and substrate removal efficiencies are obtained.

The study is also extended to the identification of microbes in the biomass of the RBC system.

Areal organic loading rate has been recognized as the major factor affecting RBC system treatment efficiency. Observations from the substrate removal trends indicate that percentage removals are reversibly related to areal organic loading rates. Meanwhile, nitrogen and metal removal trends too showed the same tendency of having percentage removals reversibly related to their respective loading rates.

Finding from this study indicate that the pilot plant is effective as secondary treatment for leachate only when it is subjected to low areal loading rates. This finding is based on the performances of removal for organic parameters, COD of which 57.3% is removed at 9.68g COD/m² day loading rates, VSS with removal of 51.4% at 0.58g VSS/m² day loading rate and SS with removal of 60.3% at 0.91g SS/m² day loading rate. Meanwhile, the pilot plant performs better with nitrogen removal, which indicates a 95.5% NH₃-N removal at loading rate of 6.09g NH₃-N/m² day. Removals of all the organic and nitrogen parameters involved (except for SS) are mostly from the biological RBC system. The physical sedimentation system removes SS effectively. The qualities of the effluent for these parameter (except for SS) are still very high compared to the parameter limits of the Standard B. meanwhile, metal removal for Fe, Mn and Ca are quite high with percentage of 90.0, 84.0 and 86.4% respectively at low loading rates of 0.0172, 0.0039 and 0.0050g/m² day. Removal of Mg and Ni are fairly good at 55.7% and 66.7% with loading rates of 0.0180 and 0.0045 g/m².day respectively. The qualities of the final effluent for these parameters complied to Standard B parameter limits.

From the microbiological analysis, two types of bacteria, *Pseudomonas stutzeri* and *Enterobacter agglomerans* are identified in the biomass of the RBC system. The rest of the microbes present are fungus types (*Staphylococcus sp.*, *Rhizopus sp.*, *Aspergillus sp.*, and *Penicillium sp.*) both types of bacteria identified are typical species found in the biomass of the RBC system. Basically, the optimal utilization of the reactor treatly leachate is its application with high loading rates. However, the unit treatment being studied is only capable of removing organic pollutants with low loading rates. Nevertheless, the situation can be overcome by implementing some modifications, which are suggested in detail in the conclusion of this thesis, for future study.





MSc. Student: Sharifah Abdullah

Supervisor

Prof. Dr. Aminuddin Ab Ghani
Prof. Dr. Nor Azazi Zakaria

Title

Simulation of Muda River Channel Changes due to Sand Mining Operations

Completion Year: 2002

Abstract

Natural river is a form of channel that easily changes in term of its physical shape such as width or depth as well as the changes in water pollution. Unplanned development couples with human and natural factors are the biggest contributors to changes in the river equilibrium. Economics activities such as agricultures, urbanisation, fishery, sand mining, etc, should be control in ensuring the balance of river eco-system. Sand mining activities are usually concentrated at the sandy-bed natural rivers. River sands are an important element in development factors, where its demand increases linearly with Malaysian infrastructure development.

The research was conducted to identify the changes of riverbed due to sand mining activities at Muda River in Kedah because of currently active sand mining operations along the river. This research consists of river cross-sectional survey, sediments sampling and water level records at seven stations along a 5 km river reach.

The extensive sand mining activities along the research area requires closed supervision and control by related authority in ensuring that erosions are minimised. The mining depth needs to be closely monitored so that sand miners do not exceed the permitted depth of Sand Mining Guideline established by Jabatan Pengairan dan Saliran Malaysia (JPS). Based on survey works that have been carried out in year 2001 and 2002, it has been found out that the sand miners have failed to fulfil the requirements of the Sand Mining Guideline given by JPS. Almost all the cross-section within the research area having width more than 50 m, have been mined exceeding 1.5 m depth of the allowable tolerance.

A mathematical model, FLUVIAL-12 (Mathematical Model for Erodible Channel, Chang, 1988) was used to forecast the changes of Muda riverbed. The calibration carried out shows that the Manning Coefficient, $n = 0.040$ is suitable for Muda River analysis. Yang Equation also gives almost an accurate result to the actual condition at research site. Selected simulation cases have successfully shown that the changes of riverbed are due to sand mining activities and flood. The results also show that the past flooding (1988, 1998) have given major effect to physical stability of the research area compared to sand mining activities.



MSc. Student: Yip Hing Wai

Supervisor

Prof. Dr. Aminuddin Ab Ghani
Assoc. Prof. Dr. Rozi Abdullah
Dato' Ir. Hj. Keizrul Abdullah

Title

Flood Runoff Estimation of Ungauged River Catchments Using Soil Conservation Service (SCS) Method

Completion Year: 2002

Abstract

The research in this project is to estimate the flood runoff from an ungauged catchment in eninsular Malaysia using the Soil Conservation Service (SCS) Method. The objective for the selection of the SCS Method is to have an alternative method to estimate the flood runoff from rural, and or mixed development for ungauged catchments in Peninsular Malaysia. The SCS Method is able to provide the volume and the peak discharge of a flood hydrograph based on the rainfall events. Before the SCS Method can be applied to an ungauged catchment, the parameters of the SCS Method need to be calibrated from the gauged catchment(s).

The gauged catchment(s) should have similar land use and physical characteristics of the ungauged catchment. The physical characteristics of a catchment are the catchment slope, and hydrologic soil conditions. The unit hydrograph theory theory is used to calibrate the SCS Method. The calibrated parameters also known as the corrected coefficients will then be applied to SCS Method to estimate the flood runoff of the ungauged catchment. The flood hydrographs derived by using the SCS Method will then be compared with the flood hydrographs derived by using the Jabatan Pengairan dan Saliran (JPS) Hydrological Procedures (HP) No. 5, 11, and 16. The HP16 is not forurbanized catchments, HP5 and HP11 are for rural catchments condition in peninsular Malaysia.

The use of Convolution Method to generate the design direct runoff hydrographs is used in the comparison study. In the calibration process, it is difficult to obtain a good rainfall-runoff relationship for the gauged catchments. The rain-runoff relationship of a catchment is determined by the ability of rainfall stations in or within the catchment boundary to capture the rainfall events. There are many hydrological records (rainfall and runoff records) in the sample catchments that are not used in the calibration process. This is due to the reason that the poor rainfall records with respect to the runoff records where high amount of rainfall recorded in one or two rainfall stations but no records of high runoff in the streamflow station of the catchment.

Other reasons are to the missing of either rainfall or runoff data for the same period of records and difficulty of isolating single storm hydrograph event where usually the storms occurred in multiple storm type. There are limitations to the usage of the SCS Method. These limitations are due to the lack of soil maps throughout the Peninsular Malaysia for soils textural classifications, soils infiltration rates and land use of the catchment. The land use of the catchment for agricultural usage for SCS Method is classified as fallow, row crops, pasture and others. However, how is the land use of the catchment relates or equivalent to Malaysian context? For urban catchment, how is the land use been equivalent to the terrace houses? With the calibration of the correction coefficients, it is able to overcome some the limitations as stated above.



MSc. Student: Ahmad Darus

Supervisor

Prof. Dr. Aminuddin Ab Ghani
Prof. Dr. Nor Azazi Zakaria

Title

Conservation and Restoration of Urban Rivers: Case Studies of Raia River and Pari River

Completion Year: 2002

Abstract

As a result of increasing economic growth of the country, areas within river catchment are being developed for commercial, industrial and housing purposes. Effect of this rapid urbanization has accelerated impact on the catchment hydrology and geomorphology. These developments have caused dramatic increase in the surface runoff and the behavior of sediment output, hence resulting in higher sediment yield.

Since any flood mitigation works would likely involve channel modification, so knowledge of predicting the geometry changes as a result of sediment transport movement is significant and necessary. By using appropriate method, channel stability and river equilibrium can be achieved.

Intensive literature review has been made on several aspect of river morphology such as characteristics of natural river, channelization works and their impact, and conservation concept toward restoration of channelized river.

Two catchments namely Raia River at Simpang Pulai, Ipoh and Pari River at Ipoh, with different land use and development were chosen for this study. Raia River represents a natural river while Pari River represents a channelized river.

Several gauging stations were identified based upon the river characteristics such as straight reach and bend. Six stations for Raia River and four stations for Pari River were selected. Sediment sizes were identified by collecting bed and bank materials from each station. Surveys of existing cross section and water level measurements were carried out for comparison purposes with the morphological changes predicted by FLUVIAL-12 and three different method of designing stable channel.

Comparisons on the three empirical design methods including maximum velocity, tractive force and regime method (Simons and Albertson, 1960) with mathematical model (FLUVIAL-12) using field's data were carried out in order to choose the appropriate method which will minimize the morphological changes in river channel. The results from the mathematical model (FLUVIAL-12) that comprises component of water and sediment routing, indicates channel changes that agrees well with the characteristics of a dynamic river. FLUVIAL-12 is also capable of predicting channel instability effect such as erosion and sedimentation at straight reach and bend for both Raia and Pari River.

Simulation results based upon FLUVIAL-12 also indicate that Raia River can be conserved as a natural river by maintaining cross section with a side slope of 1:2. By ensuring the Manning's roughness coefficient to be 0.025 and a cross section with a side slope of 1:2, Pari River can be restored as a natural river without the concrete bank.

MSc. Student: Ahmad Bakri Abdul Ghaffar

Supervisor

Prof. Dr. Aminuddin Ab Ghani

Assoc. Prof. Dr. Rozi Abdullah

Title

Determination of Manning's Flow Resistance Coefficient for Kinta River Basin

Completion Year: 2003

Abstract

Natural channel morphology depends on the interaction between fluid flow and the erodible materials in the channel boundary. Velocity is strongly related to flow resistance, which is one of the most important elements in the interaction between fluid flow and the channel boundary. Computations involving flow in open channels commonly require an evaluation of roughness characteristic of the channel. The engineers have use a number of flow resistance equations involving grain roughness, form roughness and a combination of both, but the Manning's equation has been widely used internationally for predicting roughness values in natural channels.

In river engineering, Manning's roughness coefficient, n , has been used widely in river hydraulic models. The procedure for selecting n values is subjective and requires judgement and skill that is developed primarily through experience apart from knowing the factors that affect the values of n . Since flow and the boundary roughness vary with river conditions, a model of some form is to be developed for evaluation of n values for rivers in Malaysia. This research has been carried out at four rivers in the River Kinta Basin namely Pari River, Raia River, Kampar River and Kinta River.

A total of 122 data have been collected at six stations. Evaluations on the existing equations show that none of the equations has given a value of n which can predict satisfactorily the discharge of a river. Two new equations have been developed and found able to predict satisfactorily the discharge of rivers in Malaysia. So the use of new equations is recommended in determining the suitable value of n .





MSc. Student: Anita Ainan

Supervisor

Prof. Dr. Aminuddin Ab Ghani
Prof. Dr. Nor Azazi Zakaria

Title

An Evaluation of BIOECOLOGICAL Drainage System as an Application of Urban Storm Water Management Manual in Malaysia

Completion Year: 2003

Abstract

Rapid development has changed the land use and this will lead to an increase in the surface runoff caused by the increase of the impervious surface area. Impervious surface area will transform most of the rainfall directly as surface runoff. Hence a given rainfall now produces significantly more runoff volume than before.

Stormwater management in urban areas has changed from rapid conveyance approach to control at source that states the post development and pre-development peak flow should be the same. Department of Irrigation and Drainage has introduced Urban Stormwater Management Manual (MSMA) and directed all the new development should follow this new regulation. This regulation seeks that the quantity and quality of the surface run-off should be similar for the post and pre-development.

A numbers of Best Management Practices (BMPs) have been developed to control the quantity and quality of the surface run-off. Examples of the BMPs are wet pond, dry pond, swale, wetland and infiltration system.

The drainage system in Engineering Campus Universiti Sains Malaysia that used the control at source approach was chosen as the research site. Bioecological Drainage System (BIOECODS) is a pilot project that applied the control at source approach as described in MSMA. This research aims to evaluate the BIOECODS as one of Storm Water Management applications in Malaysia.

The implementation of the research requires a comprehensive data collection such as rainfall depth, velocity and discharge in the surface and sub-surface swale. The analysis of the data shows that BIOECODS has functioned as designed. Emptying time of ecological swale less than 24 hours is recorded in the surface and sub-surface swale after a rainfall event. Peak flow and volume attenuation also occur at surface and sub-surface swale. However the percentage of the attenuation depends on the ARI. The study of the dry pond indicates that emptying time of the dry pond also depends on the ARI. From the study the dry pond has emptying time less than 24 hours when the rainfall event is less than 2 year ARI.

Hydraulic simulation of BIOECODS using Storm Water Management (SWMM) computer model showed that peak hydrograph could be attenuated to the pre-development hydrograph. Calibration process result shows that SWMM model can simulate well in term of peak hydrograph rather than volume.

From the quality aspect, grab sampling results show that water quality at outlet type C achieves Class II A standard. The value of pH ranges between 6.5 –7.7, Dissolved Oxygen between 5.74-6.4 and BOD between 3-6 mg/l is within the range of Class IIA. The existence of heavy metal is too little and the value of phosphate and total phosphate between 0.02-0.03.

MSc. Student: Mahadzir Kassim

Supervisor

Prof. Dr. Aminuddin Ab Ghani
Prof. Dr. Nor Azazi Zakaria

Title

Sediment Deposition in a Rigid Monsoon Drain: Case Study Raja River, Alor Star

Completion Year: 2005

Abstract

Urban drainage system in Malaysia is usually based on conventional system made up of concrete drains which convey surface run-off from rapid development urban areas. This conventional design could increase sedimentation in the drains due to surface run-off which carried along sand and soil particles into the drains. This sedimentation will decrease the cross-sectional area of the drains and slowly reduce the designed hydraulic capacity of the drains. The incipient motion and sediment transport are influenced by water velocity, particles sizes (d_{50}), concentration of suspended bed load (C_v) and other factors.

The objectives of the research are to establish the deposited sediment particle size, to determine sediment deposition and corresponding slope and also to evaluate the existing incipient motion equations for self-cleansing design purposes.

The study conducted includes sampling works at Sg. Raja (10 stations) and twelve cities of Peninsular Malaysia. Particles sizes distribution analyses were carried out to determine particles sizes for use in the existing incipient motion equations. The most suitable equations can be determined to predict sediment deposition occurred in the drains based on measured deposited sediment slope.

Based on particle size distribution analyses, the sediment average size for twelve cities in Malaysia is 0.75mm while for Alor Star the average sediment size is 0.93mm. The existing incipient motion equation assessments show that Equation 2.19 (Novak & Nalluri, 1975) is able to predict satisfactorily the sediment deposited slope while Equation 2.27 (Ab.Ghani et al., 1975) is able to predict well the design slope.





MSc. Student: Abd. Jalil Hassan

Supervisor

Prof. Dr. Aminuddin Ab Ghani;
Assoc. Prof. Dr. Rozi Abdullah

Title

River and Floodplain Modelling for the Development of Flood Risk Map: A Case Study of Sg. Selangor

Completion Year: 2006

Abstract

Flood is one of the natural disasters in this country. However human activities in river basin changes flood behaviour such as increase in the flood magnitude which affects human life and properties. Structural measures to mitigate flood such as river widening and straightening, must be well understood since this kind of work may transfer the flood problem from upstream to the downstream part of the river system. Therefore an understanding of the flood behaviour is an important step in reducing the damage cause by flood. River hydrodynamic modeling using computer is able to carry out flood simulation along a river which will produce flood level along the river and floodplain.

Sg. Selangor basin was selected as the study area. This basin is located besides Klang Valley which is highly developed. It is expected that there is a potential development in the near future within this basin. The main river of Sg. Selangor is about 106 km in length with the catchment area of 1960 km². The basin has been identified having enough and suitable information to carry out the intended research.

Among input required to make the present research successful is the river cross section, floodplain information, activities in the catchment, contour, soil types and landuse. Other information on flood record such as flood level and discharge at hydrological station within the floodplain is useful for the purpose of the calibration process.

The approach use in this research is to develop a river hydrodynamic model covering the main river and its flood plain. The river tributaries are modelled as hydrologic input from the respective subcatchments. Calibrations were carried out at several locations along the river namely downstream, middle reach of the river and in the floodplain. Flood behaviour from the model is compared with 1971 flood which is the largest flood that had occurred in the basin.

The impact from land reclamation to the flood behaviour was further analysed for an area of 400 hectares along Kg Asahan. The simulation shows that water level increases from 38 mm to 128 mm at surrounding areas. Analysis between cross-section km 53 to km 67 shows that the areas flooded are 736 hectares and 889 hectares for 50 and 100 year return period respectively. The development of the flood risk map will assist the Lembaga Urus Air Selangor (LUAS), river engineer and planner in carrying out effective measures for planning and implementing of projects within Sg. Selangor river basin.



MSc. Student: Chang Chun Kiat

Supervisor

Prof. Dr. Aminuddin Ab Ghani
Assoc. Prof. Dr. Rozi Abdullah

Title

Sediment Transport in Sungai Kulim, Kedah

Completion Year: 2006

Abstract

Effect of rapid urbanization has accelerated the impact on the catchment hydrology and geomorphology. Such rapid development which takes place in river catchment areas will result in higher sediment yield and it will not only affects river morphology, but also river channel stability, causing serious damages to hydraulic structures along the river and also becoming the main cause for serious flooding in urban areas. Therefore, it is necessary to predict and evaluate the river channel stability due to the existing and future developments. This study was carried out at Sungai Kulim in Kedah state, Malaysia, by means of evaluation on sediment transport using recently observed data up to year 2006. The present study attempts to give an overview of the channel changes and sediment transport phenomena in Sungai Kulim. A total of 24 samples of bed materials were collected from four locations (CH 20000, CH 14390, CH 3014 and CH 0), and 14 river hydraulics and sediment transport data sets including discharge, bed load, suspended load and total load were collected from two locations (CH 14390 and CH 3014) from 2004 to 2006. The data were used to analyze and evaluate existing Manning equations and sediment transport equations. Attempts were also made to derive new Manning equations (Equations 4.3 and 4.4) with a correlation coefficient, $R^2 = 0.86$ for application to the moderate-size channels in Malaysia. The results of evaluation for total load equations at the two locations along Sungai Kulim show that Engelund & Hansen equation gave the best prediction for sand bed stream and yielded highest percentage of data with discrepancy ratio in between 0.5 and 2.0 (33.33% at CH 14390 and 62.50% at CH 3014). An erodible-boundary model, FLUVIAL-12 which simulates inter-related changes in channel-bed profile, width variation and changes in bed topography was selected for this study. Engelund-Hansen equation and roughness coefficient, $n = 0.030$ were selected for the model which was calibrated and validated for water surface profile and bed elevation. The comparison of the surveyed river geometry data in September 1991 and field measurements from October 2004 to November 2006 shows that there has been a change in cross section after several flood occurrences from 1991 to 2003. The predicted bed levels by FLUVIAL-12 were almost similar to the observed bed level from 2004 to 2006, this confirmed that channel bed degradation occurred along the 14.4 km study reach. The model simulation results for existing conditions, future conditions and long-term modeling show that the sediment size and channel geometry in Sungai Kulim changed significantly. However, modeled results show that future changes in cross sectional geometry will be limited and erosion along the reach will slow down from 2006 to 2016, thus Sungai Kulim was predicted to be stable at most locations.





MSc. Student: Baharuddin Ahmad Nasir

Supervisor

Prof. Dr. Aminuddin Ab Ghani
Assoc. Prof. Dr. Rozi Abdullah

Title

Peak Flow Attenuation Using Dry Pond for Existing Housing Schemes

Completion Year: 2008

Abstract

Stormwater management In Malaysia has been largely based on 1975 DID Urban Drainage Design Manual that covers essentially the planning, basis of design, flood discharge, hydraulic design of open channels, structures, storm drainage for urban streets, detention storage, erosion and sediment control and information to be submitted with design. Rapid disposal approach adopted in the first manual has led to higher occurrence of flash floods as a result of the increase in surface runoff, peak discharges, shorter flow duration and others.

Department of Irrigation and Drainage (DID) Malaysia is taking a proactive step by introducing new urban drainage manual known as Storm Water Management Manual for Malaysia (Manual Saliran Mesra Alam or MSMA). Effective from 1st January 2001 all new development in Malaysia must comply with the new guideline, which requires the application of Best Management Practices (BMPs) to control stormwater from the aspect of quantity and quality runoff to achieve zero development impact contribution. It is hope that this new strategy will be a sustainable solution to mitigate the existing flood problems but also to prevent the occurrence of such problem in the new developed area.

The present study embarked on using the stormwater management BMPs for an individual house in Kota Bharu, Kelantan. The objectives of the present study on the application of MSMA for an individual house were to seek the attenuation effect of biological swales - dry pond system and the suitability of applying the Stormwater Management Model (SWMM) in simulating rainfall-runoff for the biological swales - dry pond system. The house is actually an old government quarters occupying a land area of about 1556 m². The house was retrofitted to accommodate biological swales and a dry pond with biological subsurface infiltration modular tanks in 2001. The open channel flow was then monitored using ultrasonic water level sensor and an automatic rainfall recorder was also established on site. Data collection was started in 2002 until 2003. Nineteen events were observed especially in the months of October, November and December during the two-year study period.

The flow volume in the swale and dry pond was reduced from 2.94 % to 100 % while the reduction in peak flow ranges from 11.69 % to 100 %. For low depth rainfall events the percentages of volume captured and peak reduction are found to be totally absorbed but for higher depths there will be an outflow which is consistent within the designed limits for the system that is the system should be able to cater for a flow of 10-year ARI before development. Application of SWMM model shows that it is able to simulate the rainfall-runoff of the events for the biological swales - dry pond system used in the present study. The simulations show that the system is capable of attenuations peak flow and volume for events up to 10-year ARI.

MSc. Student: Nur Asmaliza Mohd Noor

Supervisor

Prof. Dr. Aminuddin Ab Ghani;
Assoc. Prof. Dr. Rozi Abdullah

Title

Water Quality Modelling of Constructed Wetlands in Malaysia. Case Study
BIOECODS, USM

Completion Year: 2009

Abstract

Constructed wetland is an essential component in BIOECODS. The objective of this research is to evaluate the capability of constructed wetland in removing pollutants and improving stormwater quality through data sampling and computer modeling. Data samplings were performed to determine whether the constructed wetland able to improve the quality of stormwater. Water quality parameters namely BOD, COD, DO, TSS, turbidity and copper were taken into consideration. The percentage pollutant removal for BOD was 9.7% to 80%, COD was 5.7% to 62.9%, DO was 6.5% to 17.8%, turbidity was 25.9% to 30%, TSS was 50% to 100% and TP was 24% to 46%. The sampled data were analyses using Paired Sample Test and the results are significant. Other than sampling data, this research also included the application of water quality model for constructed wetland and two models were chosen, namely PREWETT and WMod. Sensitivity analyses were conducted for both models to identify the model parameters. The model parameters of PREWETT were K_r for BOD, TP to TTP ratio for TP and V_s for TSS. Biofilm uptake rate is the model parameter for WMod. Furthermore, calibration process was conducted to identify model parameters values and evaluation process was also performed to obtain model which best represent actual condition. For PREWETT model, model parameters values that are obtained through calibration process were 0.32 day^{-1} for BOD, 0.4 for TP and 0.3 m/day for TSS and R^2 obtained were 0.525 for BOD, 0.067 for TSS and 0.479 for TP. While for WMod, the model parameter value obtained was 0.02 for TP and R^2 was 0.525. a model simulation was carried out to determine the design parameters which give effective removal efficiency of between 50-60%. The design parameters obtained were detention time of 14 days, length to width ratio of 11.7:1, depth of 0.5m and inflow of $0.05 \text{ m}^3/\text{s}$. in a nut shell, the finding from this research can be used as a guideline to design an effective constructed wetland that produce an optimum removal efficiency of pollutant.



MSc. Student: Joseph Dinor

Supervisor

Prof. Dr. Nor Azazi Zakaria;
Assoc. Prof. Dr. Rozi Abdullah

Title

The Effect of Deforestation on Catchment Response in the Tropical Climate Region: Case Study for Sungai Padas Catchment

Completion Year: 2009

Abstract

Deforestation activities have been widely known as one of the devastating factor to the river system and ecological system in a catchment. Deforestation activities at some areas within the Sungai Padas catchment has resulted in the changes of land cover particularly in Tambunan, Sook and Sipitang catchment area. The main objective of this study is to investigate the direct runoff hydrograph in Sungai Padas, due to the changes of land cover caused by deforestation activities using HEC-HMS (version 2.2.2). The design direct runoff hydrograph resulting from 2, 5, 10, 25, 50 and 100-yr ARI for 72 hours rainfall duration were applied to evaluate the effect of deforestation on catchment response. The results of the study indicated that the increase of deforestation approximately 20% has led to the increase of the runoff hydrograph peak and volume between the ranges of 3.34% to 5.71%, and 3.30% to 5.93%, respectively, based on 2, 5, 10, 25, 50 and 100-yr ARI for 72-hours rainfall duration. In addition to the evaluation of runoff hydrograph due to the land cover changes from forest area into logged forest area (disturbed forest), the model (HEC-HMS model) has also been used to evaluate the generation of runoff hydrograph resulted from the changes of land uses in the future when logged forest converted into large scale agriculture (e.g. rubber or oil palm). The result from the study indicated that the cultivation of large scale agriculture activity causes the additional increase in runoff hydrograph peak and volume compared to hydrograph resulted from the logged forest area. The overall results of the study summarized that the increase of runoff hydrograph peak at Beaufort discharge station is ranging from 3% to 6% due to 20% increase of deforestation area without cultivation, and 19% to 30% due to 20% of the total area converted from deforested area into large scale agriculture such as palm oil and rubber trees.



MSc. Student: Asnol Adzhan Abd Manap

Supervisor

Prof. Dr. Aminuddin Ab Ghani

Prof. Dr. Nor Azazi Zakaria

Title

Efficiency of Swale and Dry Pond for Stormwater Management

Completion Year: 2009

Abstract

The implementation of the Best Management Practices (BMPs) in a drainage system through the Stormwater Management Manual For Malaysia or better known as Manual Saliran Mesra Alam (MSMA), focusing on constructed swale and dry pond, was studied.

The study was carried out on the Bio-Ecological Drainage System (BIOECODS) at Engineering Campus, Universiti Sains Malaysia (USM), Nibong Tebal, Pulau Pinang, located in Kerian River Basin. Besides the implication of the swale and dry pond toward the inflow hydrograph of a series of ponds (detention pond, wetland and recreational pond known as ECOPOND) in managing stormwater quantity in development area, factors that affect the effectiveness of the swale and dry pond using hydrologic and hydraulic model were also identified.

The collected data such as rainfall, flow, water level, emptying time and infiltration rate from October 2003 until December 2008 at USM were analysed using SWMM 5 model. The simulated hydrographs for swale, dry pond, wetpond, detention pond, wetland and recreational pond were compared with recorded flow at the sites. The modeling shows that the SWMM 5 model has the accuracy up to 30% in simulating the observed hydrographs.

The integrated swale and dry pond as designed for BIOECODS has attenuated the peak flow compared to that of a concrete drain system. The SWMM 5 model shows that there is a reduction of 121.4% in peak flow. Also, the increase in peak flow is expected if several of the existing dry ponds are to be replaced for new development purposes. These results can lead to better understanding of the role of swale and dry pond that suit the Malaysia climate and environment.





MSc. Student: Liew Yuk San

Supervisor

Prof. Dr. Aminuddin Ab Ghani
Prof. Dr. Nor Azazi Zakaria

Title

Performance of Urban Stormwater Drainage System through Dry Detention Pond (Case Study: Kota Damansara, Selangor)

Completion Year: 2009

Abstract

Due to the rapid development, flooding occurred progressively. This scenario is worsened if improper drainage systems were implemented. The inattentiveness to all the problems occurred will generate the possibility for more severe flooding risk and creates further damages of property and loss of lives.

Since the implementation of Urban Stormwater Management Manual of Malaysia (MSMA) in 2001 by Department of Irrigation and Drainage, Malaysia, the Best Management Practices (BMPs) through construction of detention ponds have been encouraged. After 8 years of implementation, there is a need to reconsider the recommendation of constructing detention pond for water quantity control by evaluating performance of the constructed dry detention ponds using computer modelling.

This research focused on the evaluation of the existing and future performance under the stress of development of the existing drainage system particularly the constructed dry detention pond by using InfoWorks CS through United States Soil Conservation Services Method (SCS).

The case study is dry detention pond at Section 6, Kota Damansara, Selangor built in 1996 with the total catchment area of approximately 428 hectares. The major landuses in Kota Damansara are housing areas and shops which contribute more than 50% of impervious areas apart from forest, schools, landscape and fields.

From the research, it is found that the existing pond is functioning well and could perform well up to the design rainfall of 100-year ARI without flood on Cecawi 6/19 Road nearby. The dry detention pond could attenuate flow at the outlet of the dry detention pond at 39.94 m³/s and slower by 40 minutes for 50-year ARI and 42.36 m³/s and slower by 45 minutes for 100-year ARI events.

Under the landuse changed scenario, the existing dry detention pond could still cater the 100-year ARI design rainfall without flooding at surrounding area. The scenario show an increase in flow ranging from 8.88% to 52.95% and also increase in water depth ranging from 8.09% to 28.79% in all simulated cases for 2-, 10-, 50- and 100-year ARI. However, the time to peak after landuse changed condition is 5 minutes slower for existing scenario due to conduits full flow condition that slow down the flow to downstream.

The comparison between the existing drainage condition and drainage resized condition after landuse changed at the outlet culvert of detention pond show an increase runoff about 30% for both 50- and 100-year ARI and quicker time to peak at 10 minutes.

As overall, the dry detention pond is functioning to cater 50-year ARI recommended in MSMA. The construction of detention pond needs to be encouraged for any new housing development to control water quantity. Future development need to consider landuse changed factor which could induce in more flow generation and water volume from upper catchment area and it should be studied using the numerical approaches to solve the problem and ease the decision making processes.

MSc. Student: Siti Isma Hani Ismail

Supervisors

Mr. Zorkeflee Abu Hasan

Dr. H. Md. Azamathulla

Title

Erosion and Sediment Yield Evaluation in regards of Erosion Sediment Control Practices (ESCP)

Completion Year: 2009

Abstract

During construction, large areas of soil are exposed to the risk of water erosion due to earthworks activities. Bare slopes and drains choked with sediment can often be observed on construction sites. This erosion may result in a significant increase in sediment loads to receiving waters and the construction techniques used on site can cause offsite contamination. Erosion from the study area occurred due to the removal of the vegetation cover, high rainfall intensity and the failure of the sediment basins to function effectively. The present study aims to evaluate the erosion and sediment yield due to storm rainfall and runoff on a construction site located at Sungai Ara, Penang state of Malaysia. The soil loss was evaluated by using empirical erosion modelling namely the Revised Universal Soil Loss Equation (RUSLE), Modified Soil Loss Equation (MSLE) and Modified Universal Soil Loss Equation (MUSLE) and from the water samples taken at the study area. Results showed that large amount of sediment has being eroded from the study area. The highest annual erosion rates estimated is by using the RUSLE equation is recorded at Borehole 19 with soil loss of 7,772 tons/ha/y. By analyzing the samples collected at the Pond B, the TSS value is noted from 352 mg/l to 5031 mg/l at Inflow and 309 mg/l to 5375 mg/l at Outflow which fall under the Class V according to the classification by Department of Environment in Malaysia. However, the results shows that the measured soil loss was very much smaller compared to the calculated soil loss.





MSc. Student: Nuramidah Hamidon

Supervisors

Mr. Zorkeflee Abu Hasan
Dr. Mohd Suffian Yusoff

Title

Integrated River Basin Management (IRBM): Simulation Modeling System for Kurau River Sub-basin

Completion Year: 2010

Abstract

A river basin is an area delineated by its natural hydrological boundaries such that any rain falling on the area will drain to the river. Any activity that takes place upstream of a river basin will eventually have an impact on the quality and quantity of the river water as it reaches the downstream. Realizing the seriousness of the problems and the threat it may pose to the environment, Malaysia has embarked on a journey to practise Integrated River Basin Management (IRBM) particularly to strengthen the sustainable management of the country's natural resources. In this study, Kurau River sub-basin was selected to determine the effect of the land use changes to water quality of Kurau River sub-basin in order to support the implementation of IRBM by using Soil and Water Assessment Tools (SWAT2005) and Hydrologic Engineering Centre-Hydrologic Modelling System (HEC-HMS) mathematical models and integrates with GIS to produce spatial input data in model. This study also estimates sediment yield using SWAT2005 and to determine the suitability of HEC-HMS and SWAT2005 as Decision Support System Tools for IRBM. Two scenarios were set to stimulate the land use behaviours in Kurau River Sub-basin in terms of runoff hydrograph and sediment yield using United States Soil and Conservation Services (SCS) method. Land use in 2004 and 2015 were used to perform the simulations. First scenario is according to the planning by Town Planning Department for Larut Matang 2015 Local Plan then second scenario is assumed that the entire sub-basins were having 20% increase of CN. Both scenarios were applied using HEC-HMS and SWAT2005 model. Scenario simulation following Larut Matang 2015 Local Plan produces an increase of peak flow at Pondok Tanjung Station by 4.67% ($3.20\text{m}^3/\text{s}$) as compared to Batu 14 station by 20.40% ($1.90\text{m}^3/\text{s}$). Meanwhile for scenario simulation 20% increase of CN for all Sub-Basins results shows an increase of peak flow at Pondok Tanjung station by 20.46% ($14.00\text{m}^3/\text{s}$) compared to Bt 14 station by 35.48% ($3.30\text{m}^3/\text{s}$). Scenario simulation by 20% development for all subbasin for SWAT2005 also shows an increase of peak flow by 6.06% ($15.14\text{m}^3/\text{s}$) compared to scenario following Larut Matang 2015 Local Plans shows an increase of peak flow by 1.92% ($4.80\text{m}^3/\text{s}$). As for the suspended sediment, scenario simulation by 20% increase of CN for all sub-basins shows an increase of sediment by 80.88% (16,887.39 tonnes/day) compared to scenario following Larut Matang 2015 Local Plan shows an increase of sediment by 50.86% (11,454.75 tonnes/day). The result shows that land use 2015 is suitable for future planning in Kurau River Sub-basin in terms of hydrology but suspended sediment shows an increase. Proper planning by responsible agencies should be taken in order to avoid the negative environmental impact on land use in Kurau River Sub-basin. Result also demonstrated that HEC-HMS and SWAT2005 is a modelling tool for analyzing hydrological processes and water quality planning and management in the Kurau River Sub-basin.

MSc. Student: Kee Li Choo

Supervisors

Prof. Dr. Nor Azazi Zakaria

Dr. Lau Tze Liang

Title

Determination of Flow Resistance in Modular Open Channel

Completion Year: 2011

Abstract

Storage tank module is a lightweight modular system which commonly used as underground storage tank for rainwater harvesting. This storage tank module promotes reuse of rainwater, infiltration of surface water and water quality improvement. In sustainable stormwater drainage designed by River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia (USM), this storage tank module was used as underground conveyance conduit integrated with grassed swale. There are two types of modular channel investigated in this study which is the existing and newly designed modular channel which is known as Modular Channel Type A and Modular Channel Type B respectively. In this study, a total number of 54 sets of experimental and field had been analyzed in order to investigate the hydraulic characteristics of Modular Channel Type A. Meanwhile, a total number of 30 sets of experimental tests were carried out in investigating flow in Modular Channel Type B. Investigation concerning the variation of Manning's n with hydraulic parameters which include of flow depth, flow rate, Froude number and Reynolds number were also presented in this study. The analysis indicated that there were good correlations between Manning's n and Froude number with correlation of coefficient (R^2) more than 0.93. A design step of modular channel was proposed by utilizing the relationship between Manning's n and Froude number using iteration. Apart from this, simplified equations by using only aspect ratio and channel slope were developed by using multiple non-linear regression and genetic programming. It shows that prediction by using genetic programming tends to underestimate flow rate for field data. Information reported in this study can be used to estimate the hydraulic characteristics of modular under different condition.



MSc. Student: Noor Fareezianna Noor Shahidan

Supervisors

Mr. Zorkeflee Abu Hasan

Prof. Dr. Mohd Zulkifly Abdullah

Title

Flow and Sediment Pattern Simulation at Ijok Intake, District of Larut Matang, Perak

Completion Year: 2011

Abstract

Understanding the sedimentation processes in the river engineering and hydraulic structures are of vital importance as this can affect water supply for the agricultural lands in the command area. To understand the problem, a framework of physical and mathematical modelling were applied for investigate the flow and sediment pattern at Ijok Intake, Ijok River, Malaysia. HEC-RAS (1D modeling) and CCHE2D (2D modeling) software were used as the mathematical model where results from HEC-RAS were used as input for CCHE2D. Physical model was designed and constructed with a 1:15 undistorted scale at REDAC physical model laboratory. The comparative study using both models was performed by running simulation for ten different conditions without and with an intake structure. Based on the results, both models proved similar sedimentation pattern and sediments were accumulated in front of intake structure, hence reduce the flow capacity to convey water into the canal downstream. For simulation using intake structure, physical model is able to predict the flow and sediment transport phenomena accurately because CCHE2D model used simplification and modification to represent an intake structure. However, analyses proved that CCHE2D as two-dimensional mathematical model was able to give similar results of flow and sediment pattern as physical model. Thus, it can be concluded that combination of physical and mathematical model can give advantages in analyzing the river sedimentation near an intake structure for further design mitigation works.





BIODIVERSITY @ USM ENGINEERING CAMPUS

5.3 CURRENT RESEARCH STUDENTS

PhD	Name	Supervisor	Title
	Sabariah Musa	Prof. Dr. Nor Azazi Zakaria Dr. Lau Tze Liang	Drain System in Flat Area with Low Infiltration Rate using Groundwater Recharge Well
	Noor Aliza Ahmad	Prof. Dr. Aminuddin Ab. Ghani Prof. Dr. Nor Azazi Zakaria	A Study On The Hydraulic Resistance And Stability Of Vegetation In Open Channel
	Muhammad Shubhi Nurul Hadie	Mr. Zorkeflee Abu Hasan Prof. Dr. Aminuddin Ab. Ghani	Flow Estimation for Flooding Tropical Natural River
	Zahra Zangeneh Sirdari	Prof. Dr. Aminuddin Ab. Ghani Mr. Zorkeflee Abu Hasan	Bed Load Transport for Small Streams: Case Study of Kurau River
	Reza Mohammadpour	Prof. Dr. Aminuddin Ab. Ghani Dr. H Md Azamathulla	Bridge Abutment Scour Prediction and Protection
	Ahmad Bakri Abdul Ghaffar	Prof. Dr. Aminuddin Ab. Ghani Dr. H Md Azamathulla	Determination of Flow Resistance Coefficient through Genetic Programming
	Chang Chun Kiat	Prof. Dr. Aminuddin Ab. Ghani Dr. H Md Azamathulla	Determining Optimum Flood Protection Levels in River Management: Case Study of Sungai Pahang
	Ravikanth Chittripolu	Dr. Lau Tze Liang Dr. H Md Azamathulla Prof. Dr. Aminuddin Ab. Ghani	Efficiency of REDAC Gross Pollutant Trap
	Charles Bong Hin Joo	Prof. Dr. Aminuddin Ab. Ghani Dr. Lau Tze Liang	Incipient Motion and Design of Flushing Gate for Sediment Mixtures in Rigid Rectangular Channels
	Mohd Azlan Mohd Yusoff	Dr. H Md Azamathulla Mr. Zorkeflee Abu Hasan	Pipeline Scour in River Environment
	Husna Takaijudin	Prof. Dr. Aminuddin Ab. Ghani Dr. H Md Azamathulla Prof. Dr. Nor Azazi Zakaria	Development of Bioretention Facility: Benchmarking the Hydraulic Conductivity of Filter Media under Saturated and Non-saturated Condition.

Mohamad Suaimi Bin Ramli	Mr. Zorkeflee Abu Hasan Prof. Koh Hock Lye	Mathematical Modelling for Assessment of Pollution Loading for Study of Water Quality Sungai Raja, Alor Setar, Kedah
Arniza Fitri	Mr. Zorkeflee Abu Hasan Prof. Dr. Aminuddin Ab. Ghani	Determining the Effectiveness of Harapan and Aman Lakes as Flood Retention Pond at USM Main Campus
Lee Wai Hong	Dr. Lau Tze Liang Assoc. Prof. Dr. Rozi Abdullah	Discharge Estimation for Over-bank Flow Using a Modified Darcy-Weisbach Equation - A Case Study
Mohd Safwan Sulaiman	Mr. Zorkeflee Abu Hasan Prof. Dr. Aminuddin Ab. Ghani	Case Study : Analysis of The Delivery Efficiency of Terusan Selinsing, Rancangan Pengairan Kerian
Baharudin Ahmad	Mr. Zorkeflee Abu Hasan Dr. H Md Azamathulla	Flood Mitigation Assessment of Sungai Tupai, Taiping
Mohd Fazly Yusof	Assoc. Prof. Dr. Rozi Abdullah Dr. H Md Azamathulla	Rehabilitation of Tasik Harapan and Tasik Aman in USM Campus as a Sustainable Stormwater Facilities
Leow Cheng Siang	Assoc. Prof. Dr. Rozi Abdullah Prof. Dr. Nor Azazi Zakaria	Urban Catchment Modelling For Development of Stormwater Management Master Plan
Beh Chun How	Prof. Dr. Aminuddin Ab. Ghani Prof. Dr. Nor Azazi Zakaria	Water Quality Modelling to Assess Stormwater Purification of BIOECODS
Rayhana Sarento Pangilan	Dr. Lau Tze Liang Prof. Koh Hock Lye	Flood Mitigation Assessment of Sungai Maka, Tanah Merah, Kelantan
Ewe Teik Tsia	Dr. Lau Tze Liang Prof. Dr. Nor Azazi Zakaria	Verification of Flow Attenuation for Detention Pond with Field Data
Nor Zaimah Che Ghani	Mr. Zorkeflee Abu Hasan	Hydrologic Modelling for Small Urban Catchment Area : Case Study of Sg. Raja, Alor Setar, Kedah
Goh Jo Lyn	Prof. Dr. Nor Azazi Zakaria	The Synergy of Water-Soil-Plant for Water Quality Improvement in Bioretention Facilities.

5.4 MIX-MODE PROGRAMME

Masters of Science (Sustainable River Management)

This programme is intended for engineers from government sector such as Department of Irrigation and Drainage, Department of Environment, Public Works Department and other local authorities. All students will be provided with updated knowledge and modules and research will be based on the real research carried out by REDAC. Thus, students will gain better knowledge in the real work condition by this continuously education technique.

The lecturers involved in teaching this course will be those from REDAC, the School of Civil Engineering, the School of Humanities and the School of Biological Sciences.

It is hoped that this programme will bring awareness to the general public and help us to preserve our rivers and improve our drainage systems which will give impact directly on our lives as Malaysia progresses into becoming a developed nation.

The course structure consists of three components:

- i. Core Subjects (16 units)
Offered to develop specialization in sustainable river management by providing and conveying knowledge of related subjects in depth.
- ii. Elective Subjects (4 units)
General subjects which supplement core subjects. These elective courses are offered to expand the knowledge of students in related fields other than the core specialization.
- iii. Research Project Dissertation (20 units)
Aimed to enable students to carry out individual research in courses offered. Students will be asked to carry out site investigation, problem solving, writing and result presentation in the form of thesis report.

Mix Mode Dissertation

Name	Supervisor	Title
Noor Azma Lui	Dr. Lai Sai Hin	Water Quality in Constructed Wetland: A Case Study with Modeling
Mohd Azlan Mohd Yusoff	Dr. H Md Azamathulla	The Performance of REDAC (USM) Gross Pollutant Trap
Rosma Aina Roslan	Dr. Lai Sai Hin	Discharge Estimation For Flooding River Using Adaptive Neural Fuzzy Inference System (ANFIS) and Genetic Programming (GP)
Mohd Hanif Ismail	Mr. Zorkeflee Abu Hasan	Hydrologic Modelling For Sg Maka, Tanah Merah, Kelantan
Nusaibah Mohamed Yusof	Mr. Zorkeflee Abu Hasan	Modelling of Sedimentation Pattern in Bukit Merah Reservoir
Rozaini Ramli	Dr. Lai Sai Hin	Determination of Soil Erodibility, K Factor For Malaysian Soil Series
Shahnisfanizam Yaacob	Dr. H Md Azamathulla	Prediction of Scour Below Submerged Pipeline Crossing a River Using Genetic Programming
Mohd Aminur Rashid	Mr. Zorkeflee Abu Hasan	Developing a Probabilistic Flood Plain Boundary of Maka River using Hydraulic Model
Zahra Zangeneh Sirdari	Prof. Dr. Aminuddin Ab.Ghani	Effect of Channelization on the Stability of Kulim River



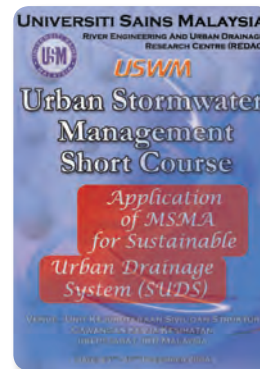
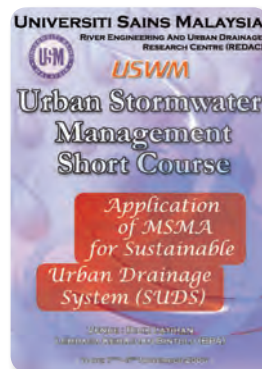
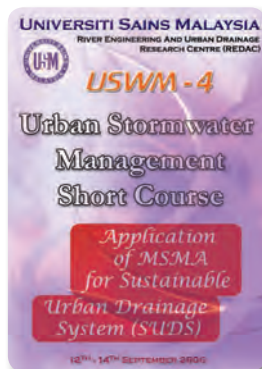
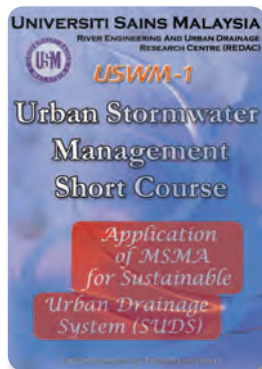
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REDAC
ACTIVITIES

6.1 SEMINAR & COURSES

Urban Stormwater Management Short Course (USWM): Application of MSMA for Sustainable Urban Drainage System (SUDS)



Date/Venue:

- | | |
|---|--|
| 30 th Nov - 2 nd Dec 2004 | - USM Engineering Campus |
| 13 th - 15 th Dec 2004 | - Unit Kejuruteraan Sivill Dan Struktur, Cawangan Kerja Kesihatan, JKR |
| 26 th - 28 th Apr 2005 | - USM Engineering Campus |
| 6 th - 8 th Sept 2005 | - USM Engineering Campus |
| 12 th - 14 th Sept 2006 | - USM Engineering Campus |
| 7 th - 8 th Nov 2006 | - Bintulu Development Authority, Sarawak |



Background:

Urbanization results in the growth and spread of impervious areas and a diversification of urban land use practices with respect to the hydrologic and environmental terms. Land use changes from rural to urban or industrial areas cause local runoff impacts on receiving water flow, quality and ecology. New, comprehensive and integrated stormwater management strategies are now needed to be in line with the government's drive to achieve a sustainable developed nation status in the early 21st century. Such new strategies will incorporate interalia, runoff source control, management and delayed disposal on a catchment wide, proactive and multi-functional basis.

The present drainage guideline, "Manual Saliran Mesra Alam" (MSMA) or Urban Stormwater Management Manual for Malaysia, which was published by the Department of Irrigation and Drainage (DID) in 2000 and gazetted by the Federal Government in 2001 will be discussed in this short course.

Objectives:

- (a) To present the new design, concepts, criteria and regulatory requirements of MSMA
- (b) To present examples of constructed projects based on MSMA
- (c) To perform design calculation for urban drainage system that complies with MSMA



Urban Stormwater Management Seminar: Stormwater Quality Management Seminar (USWM-5)



Date: 9th - 11th January 2007

Venue: Sunway Hotel, Seberang Jaya, Penang

Background:

This seminar launches the last phase of MSMA, which since inception in 2001, has gained large ground in changing the way stormwater is managed in urban areas in Malaysia. MSMA essentially consists of three parts:-

- (i) Stormwater Quantity Management – concept of 'source control' is now accept practice in all local authority areas in Peninsular Malaysia. Expertise, especially in design, needs more dissemination and development.
- (ii) Erosion and Sediment Control- Targeted for the Earthworks stage. Still in 'Introductory' stage after 1 year. Awareness abd expertise need development.
- (iii) Stormwater Quality Management- Yet to be introduced to Local Authorities and Practice On-Site, although the subject of Gross Pollutant Traps (GPT) and Swales has been broached.

In the coming years, it is expected that Stormwater Quality Management will take on increasing importance, in line with increasing efforts to clean up and rehabilitate rivers in the country.



Urban Stormwater Management Seminar: Seminar on Erosion and Sediment Control (ESC)

Date: 9th - 11th January 2007 (USWM-6) & 25th - 27th August 2008 (USWM-8)

Venue: Parkroyal Hotel & Resorts, Penang



Background:

Sediment from earthworks is the biggest source of pollution to rivers in the country. This is readily evident from the 'teh-susu' colour of our rivers, especially in urban areas. It has also been verified by numerous studies on river basins commissioned by the DID. Yet, sadly, not much has been done to contain this very damaging aspect of development.

Not only are river aquatic life (fish, prawns etc) and ecology seriously depleted but marine ecology is also affected, as large sediment loads continue to spread along the coastline - smothering out spawning grounds and coastal sea-beds. Inland, sediment chokes up culverts and river-beds, increasing flash-flood frequencies. Engineers supervising earthworks must be trained to be competent in 'Erosion and Sediment Control (ESC)'. ESC Plans (ESCP) need to be prepared by competent professionals and implemented by contractors who also need exposure in this field. Obviously, Malaysia has a long way to go judging from the limited expertise available in the country at present. This course conducted by an experienced practitioner and trainer from USA is a must for engineers (and related professionals) to understand control practices in a developed country. USWM-6 was held in conjunction with the first examination for CPESC in the country for 15 candidates from the government and the private sector and USWM-8 was held in conjunction with the second examination for CPESC for 100 candidates from the government and the private sector.



Seminar Pematuhan MSMA untuk Kelulusan Pelan Pembangunan di Malaysia: Seminar Pematuhan MSMA untuk Kelulusan Pelan Pembangunan di Malaysia



USWM-7: **Date:** 27th - 28th May 2008
Venue: The Grand BlueWave Hotel, Johor Bharu

USWM-7b: **Date:** 30th - 31st July 2008
Venue: The Grand BlueWave Hotel, Shah Alam

Background:

In April 2007, the Malaysian government under the Ministry of Housing and Local Government initiated a One-Stop-Centre (OSC) approval process in an effort to improve the delivery system and procedures at all state municipalities. Its main purpose is to ensure that Malaysia stays globally competitive in the property and real estate sectors. It is an independent body that acts as a facilitator for the planning process for submission of plans at the local authority. Therefore, a standard submission procedure for stormwater was developed in line with the OSC by Department of Irrigation and Drainage (DID) Malaysia for submission and approval of land development initiated by the Ministry of Housing and Local Government. This standard submission procedure is part of the strategy of DID being the relevant administrative agency for stormwater management in getting all parties involved such as planner, consultant, project owner/developer, contractor and the local authorities to improve their understanding and practices and achieve the required development control objectives. As Urban Stormwater Management Manual for Malaysia (MSMA) is now mandatory for new development, there is a need for consultants to quickly develop expertise in MSMA and familiarize themselves with the requirements for stormwater quality and ESCP. This need is more pressing for some consultants due partly to their lack of adequate exposure to MSMA during the earlier stages of its implementation. This set of checklist has been produced to assist developers, contractors and consultants on the proper use of MSMA and to ensure better compliance to the measures in the Manual.

The Submission Checklist for Stormwater Management in Malaysia (DID, 2008) include 4 review checklist as follows:-

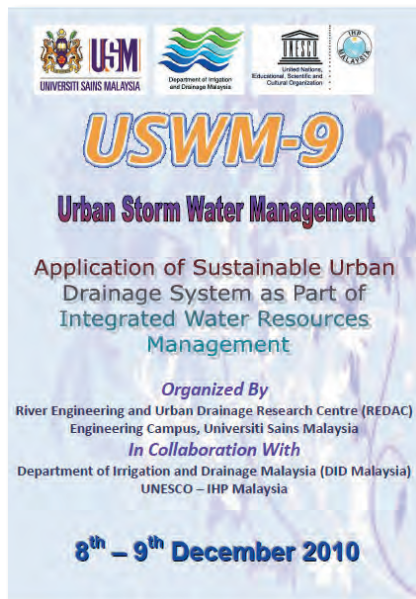
- i) Submission of Plan for Planning Permission
- ii) Submission of Plan for Drainage and Stormwater Management
- iii) Submission of Plan for Erosion and Sediment Control Plan
- iv) Erosion and Sediment Control - Inspection and Maintenance of BMP's.



Urban Stormwater Water Management Seminar: Application of Sustainable Urban Drainage System as Part of Integrated Water Resources Management (USWM-9)

Date: 8th - 9th December 2010

Venue: USM Engineering Campus



Background:

Integrated Water Resources Management (IWRM) has been as one of the most significant development in water resources management in many years which inspired by the four Dublin Principles. IWRM can be define as a process which promotes the coordinated development and management water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (Global Water Partnership). It is important that the practitioners to have a good information and implement guidance in use IWRM within developments. In order to achieve IWRM, it should start with changing the ideology of water resources management. Thus, stormwater management can be first issue to focus.

The drainage guideline Urban Stormwater Management Manual for Malaysia (MSMA) which was published by Department of Irrigation and Drainage (DID) in 2001 will be discuss in this short course. It is also hope that the practitioner in this short course will have a better understanding and guidance in planning, designing and managing IWRM concept by implementing Sustainable Urban Drainage System (SUDS) or MSMA.



International Workshop on Urban Stormwater Management: Malaysian Experiences



Date: 1st - 2nd July 2009

Venue: USM Engineering Campus

Background:

REDAC had made a technical visit to Center of Environmental Engineering (CEE), Vietnam on December 27, 2008 to share knowledge and experience in urban drainage and river management. During CEE upcoming visit to Malaysia in this July 2009, REDAC gladly arrange the International Workshop on Urban Stormwater Management: Malaysian Experiences for which staff of CEE would receive useful inputs on related issues in urban drainage and river management.



Urbanization results in the growth and spread of impervious areas and a diversification of urban land use practices with respect to the hydrologic and environmental terms. Land use changes from rural to urban or industrial areas cause local runoff impacts on receiving water flow, quality and ecology. New, comprehensive and integrated stormwater management strategies are now needed to be in line with the government's drive to achieve a sustainable developed nation status in the early 21st century. Such new strategies will incorporate interalia, runoff source control, management and delayed disposal on a catchment wide, proactive and multi-functional basis.

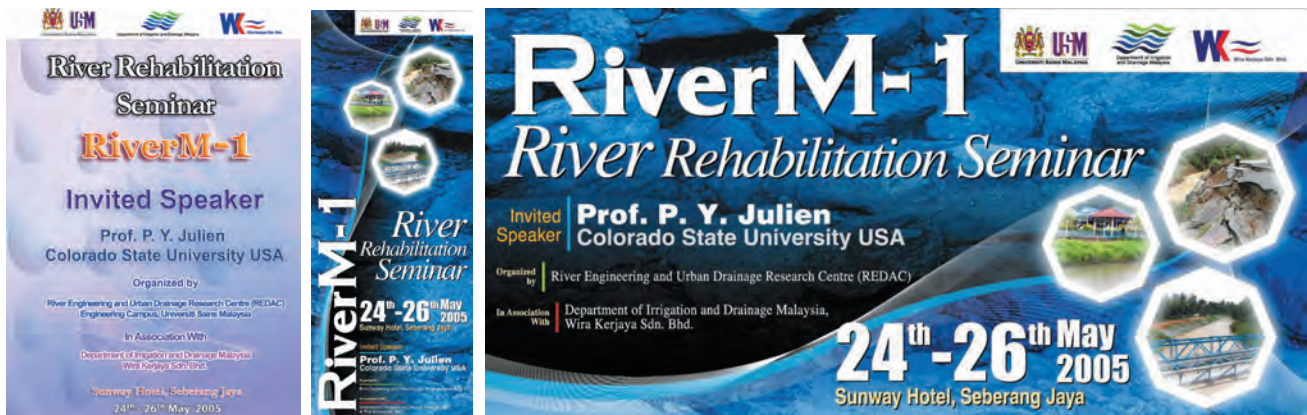
The present guideline, Urban Stormwater Management Manual for Malaysia (MSMA), which was published by the Department of Irrigation and Drainage (DID) in 2000 and gazetted by the Federal Government in 2001 will be discussed in this workshop. Basically the manual comprises all the Best Management Practices (BMPs) and Sustainable Urban Drainage Systems (SUDS) techniques based on Malaysian condition.

Objectives:

- To present the new design, concepts, criteria and regulatory requirements of MSMA
- To perform design calculation for urban drainage system that complies with MSMA
- To share experiences based on examples of constructed projects in urban drainage and river management in Malaysia



River Rehabilitation Seminar (RiverM-1)



Date: 24th – 26th May 2005

Venue: Sunway Hotel, Seberang Jaya, Penang

Background:

Streams and rivers vary in character from place to place: from headwaters to mouth and from region to region. They also change over time, rapidly during floods and gradually over much longer periods. These phenomena are part of urban as much as natural rivers, and must be understood if we are to achieve and sustain urban renewal. In their natural state, river corridors offer many benefits. These include clean water, productive fisheries, a diverse range of plants and wide life in and out of water, navigation routes, and flood storage reservoirs (flood plains). But as rivers and their valleys become altered through urbanization, some of these benefits are lost and others become degraded and more costly to sustain.

The rehabilitation of degraded rivers is of growing interest to practitioners of river management worldwide. In urban areas, this interest has been raised by the recognition of the value of river corridors for amenity, recreation, and nature conservation, and the role of river corridors in enhancing the quality of urban living and in connecting different parts of the landscape. Today, the approach is to hold back flood waters (Sustainable Urban Drainage System), to restore flood plains and to create suitably designed flood and balancing areas with an interlinked green – and traffic free – network of river corridors. These corridors serve to connect different areas of the city, and sites of cultural and natural heritage.



Sediment Transport Modeling Workshop (RiverM-2)

Date: 28th - 30th July 2009

Venue: USM Engineering Campus

Background:

USAINS HOLDING Sdn Bhd through River Engineering and Urban Drainage Research Centre (REDAC) has been appointed by Jabatan Pengairan dan Saliran Malaysia to carry out Study On River Sand Mining Capacity In Malaysia. The study covers three rivers i.e Sungai Muda, Sungai Langat and Sungai Kurau that have different level of sand mining activities. Sungai Muda has a long history of sand mining activity along the upper reach. Sungai Langat recently has been a major source of sand for construction with the development of Putrajaya. Fewer activities of sand mining are on-going in Sungai Kurau at the upstream of Bukit Merah reservoir. The objectives of the study include the assessment of the river morphology, hydrological and sediment transport modelling and development of river register database. Field works on selected sites for the three rivers were made to assess the capacity of the river to convey both water and sediment. Data collection on bed material was made to characterize the physical characteristics of sediment responsible for sediment transport that determines the river response in terms of erosion and deposition. Hydraulic and sediment transport modeling study were carried out to determine possible location of deposition along the three rivers in the present study. The depth and volume of deposition will in return determine the viability of sand extraction taking into account the ability of the rivers to replenish the sediment.

Objectives:

- To carry out hydraulic/sediment transport modeling study incorporating both the river and its capacity to sustain sediment extraction according to the sediment balance within the catchment
- To formulate a long term solution encompassing sand mining envelope along the river stretch in terms of both river morphology and hydraulic/sediment transport modeling
- To achieve a balance between theory and practice



Hands On Training in River Sediment Sampling (RiverM-3)

Date: 23rd - 25th November 2010

Venue: USM Engineering Campus

This training course was specially tailored to suit the specific target groups of technical staff from National Hydraulic Research Institute of Malaysia (NAHRIM) on good practice and correct handling of equipments during river sediment sampling. This training started with a half-day theoretical briefing by experienced and skilled REDAC staff. Then participants are transferred to a sampling site, i.e. Sungai Kurau, to experience hands on training for sediment sampling (bed material, bed load and suspended load) in rivers. After demonstration by skilled technicians of REDAC, participants were then given opportunity to try out the sampling procedure themselves under guidance of REDAC technicians.

On the final day, the participants were guided through the various common laboratory tests being carried out to analyse a typical sediment sample, which included dry sieve analysis and hydrometer test. The samples collected the previous day were used in this exercise. Participants are allowed to carry out the tests on their respective samples. The final part of the training course include the interpretation of the obtain laboratory test results. Participants were thought on how to translate the test results into meaningful information. The entire course provided a full package training from preparation and equipment handling, to laboratory testing and result interpretation of river sediment samples.

The objectives of the training course were:

- To provide exposure to participant on the appropriate handling of various equipments used in river sediment load sampling
- To provide exercise for the participants on river sediment transport data collection and analysis
- To provide sufficient training to participants on laboratory analyses for river sediment samples



6.2 INTERNATIONAL CONFERENCES

1st International Conference on Managing Rivers in the 21st Century: Issues & Challenges

Date: 21st - 23rd September 2004

Venue: Penang



Rivers'04 was organized by River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia (USM) as the first conference in the series of triennial International Conference on Managing Rivers in the 21st Century for the purpose of providing a major forum to researchers and engineers from national and international levels to present and exchange their views on the latest research issues and application methods to solve existing problems related to rivers in Malaysia and worldwide. 150 participants from seven countries (Malaysia, Iran, UK, Australia, Finland, India, USA) attended the three-day conference. The official opening of Rivers'04 was made by His Excellency the Head of State of Penang on 21st September 2004. A special publication on a pilot project on Urban Storm Water Management called "Bio-Ecological Drainage System (BIOECODS)" was launched

by His Excellency during the official opening ceremony. Also, Prof. Roger Falconer, a council member of IAHR graciously launched the IAHR Student Chapter – Universiti Sains Malaysia, the first of its kind in the Far East. The founding committee members of the IAHR SC – USM are Mr. Abd. Jalil Hasan (President), Mr. Mohamad Ansar Derani (Vice President), Mr. Chang Chun Kiat (Secretary), and Mohd Fazly Yusof (Treasurer).

Government agencies and research institutions at national level and a prestigious international professional society

supported this conference. These include: Department of Irrigation and Drainage (DID), Malaysia, Malaysian National Committee on Irrigation and Drainage (MANCID), Humid Tropics Centre (HTC), Universiti Teknologi MARA (UiTM), Institute for Environment and Development (LESTARI), National Hydraulic Research Institute of Malaysia (NAHRIM), and International Association of Hydraulic Engineering and Research (IAHR).

Rivers'04 highlighted issues dealing with managing rivers such as flash flood, urban drainage, water scarcity, water pollution, catchment management, and river conservation. The challenge ahead in managing rivers remain to be evaluated and applied so as to preserve the natural environment of existing rivers in recognition of the developments that are coming to river basins. Among the challenges ahead are designing a Sustainable Urban Drainage System (SUDS), River Restoration by applying "Back to Nature" approach, and Integrated River Basin Management (IRBM). As such the four Keynote Speakers who are renowned experts from national and international levels namely Prof. Roger A. Falconer (Cardiff University, UK), Prof. Pierre Y. Julien (Colorado State University, USA), Datuk Ir. Hj. Keizrul Abdullah (President, International Commission on Irrigation and Drainage, ICID), and Prof. Chan Ngai Weng (Water Watch Penang, WWP) opened Rivers'04 with their Keynote Addresses on the subjects of Sustainable Management, River Restoration and Environmental Modeling in River Basin Management. The presented papers were published into two parts: a Book of Proceedings and the CD-ROM Proceedings. Both contain 75 papers selected from 100 abstract submissions, covering the four major topics: River Hydraulics &

Hydrology (30 papers), River Management (27 papers), River Modeling (12 papers), and Case study (6 papers). These papers were presented by authors in five technical sessions divided into three parallel sessions. 30% of the papers are from international participants whereas the rest 70% from local participants including those from research institutions, NGOs and government agencies.

Two technical visits were also conducted during the second day of the conference. The first visit was to the BIOECODS project at the USM Engineering Campus. The participants were able to see themselves the application of several options of Best Management Practices (BMPs) in urban storm water management to reduce flash flood, water scarcity and water pollution. The second visit was to the USM Marine Research centre at Muka Head.

ISBN 983-3067-08-5 (Proceedings)

ISBN 983-3067-09-3 (CD-ROM)

ISSN 1571-5124 (Special Issue Rivers'04, International Journal River Basin Management, IAHR & INBO, Vol. 3, No. 3)





**2nd International Conference on Managing Rivers in the 21st Century:
Solutions Towards Sustainable River Basin
Date: 6th - 8th June 2007
Venue: Kuching, Sarawak**

Rivers'07 was co-organised by River Engineering and Urban Drainage Research Centre (REDAC) of Universiti Sains Malaysia (USM) and the Sarawak Rivers Board (SRB). The conference is the second of a series of triennial International Conference on Managing Rivers in the 21st Century. This series of conference is aimed to provide a major forum for researchers and engineers to present and exchange their views on the latest research issues and application methods to solve existing problems related to rivers in Malaysia and worldwide.

The conference was supported by government agencies, research institutions and professional societies, which include Department of Irrigation and Drainage (DID) Malaysia, Malaysian National Committee on Irrigation and Drainage (MANCID), Humid Tropics Centre (HTC), Institute for Environment and Development (LESTARI), Universiti Teknologi MARA (UiTM), National Hydraulic Research Institute of Malaysia (NAHRIM), Water Watch Penang (WWP), Sarawak Development Institute (SDI) and International Association of Hydraulic Engineering and Research (IAHR).



The three-day conference was attended by 154 participants including exhibitors from eight countries including UK, USA, Singapore and Malaysia. The official opening was made by YB Datuk Patinggi Tan Sri Dr. Alfred Jabu Anak Numpang, Deputy Chief Minister of Sarawak, representing the Right Honourable Chief Minister of Sarawak, Pehin Sri Haji Abdul Taib Mahmud on the 6th of June, 2007. Event on the first day, 4 keynotes speeches were delivered by established speakers namely, YB Datuk Patinggi Tan Sri Dr. Alfred Jabu Anak Numpang (Deputy Chief Minister of Sarawak, Malaysia), Datuk Paduka Ir. Hj. Keizrul Abdullah (Director-General of DID Malaysia), Professor Roger A. Falconer (Cardiff University, UK), and Professor Jörg Imberger (University of Western Australia, Australia). The keynote addresses touched on river management, river restoration and developments in river modelling. Later that evening, participants were invited for a state dinner, sponsored by the Sarawak State Government. Cultural performances from the indigenous tribes of Sarawak delighted the guests, which include the Deputy Chief Minister himself.

The second day of the conference was dedicated to the presentation of papers. There were two parallel technical sessions held concurrently, covering eight sessions in total. Various issues and new developments were presented and discussed by participants from various backgrounds. Among the topics brought up were Integrated River Basin Management (IRBM), advancement in 2-D hydraulic modelling, real time water quality monitoring and forecasting, localised effort in restoring and managing rivers, as well as inland river navigation systems. Professor Dr. Nor Azazi Zakaria (Universiti Sains Malaysia, Malaysia) addressed his keynote speech on the final day of the event, highlighting on the importance of Sustainable Urban Drainage Systems (SUDS). Two technical sessions followed, before the Chairman of Sarawak River Board, YB Datuk Dr. Stephen Rundi Anak Utom addressed his speech to officially bring the curtain down on Rivers'07 International Conference. Later, participants were treated to a river cruise ride down the Sarawak River to the Sarawak River Barrage and back. The participants were briefed through the operation of the barrage system in mitigating flood and protecting the city against intruding tide in the half-hour stay at the barrage.

A part from the involvement of participants, the success of conference was also due to contribution by the exhibitors, government agencies, private companies and NGOs participated in the exhibition. The exhibitors were active in promoting their products and services, which include state-of-the-art surveying techniques, material innovations, and water quality test apparatus. The official opening of the exhibition was done by the Deputy Chief Minister of Sarawak, right after the official launching of Rivers'07 International Conference.



The papers presented in the conference were compiled into CD-ROM Proceedings. There were 88 papers included in the proceedings, systematically arranged into ten topics of, Integrated River Basin Management (12 papers), Watershed Land Use Planning and Management (5 papers), Flood Forecasting and Flood Risk Management/Mitigation (10 papers), Floodplain, River and Estuarine Rehabilitation (13 papers), Hydrology and Sustainable Drainage System (17 papers), Stream Heritage Restoration and Conservation (1 paper), Water Quality Treatment (9 papers), Inland Water Transport (3 papers), Soil Erosion and Sedimentation (16 papers), and Legislative and Policy (2 papers). 40% of the papers were from international participants whereas the remaining 60% were from local participants including research institutions, NGOs and government agencies. The CD-ROM proceeding is priced at USD 75 (RM 250) and can be obtained from Professor Dr. Aminuddin Ab. Ghani (redac02@eng.usm.my).

Overall the organizing of Rivers'07 International Conference can be described as successful. All parties have contributed their 100% effort and commitment towards this conference. Congratulation to the organizer, Universiti Sains Malaysia under River Engineering and Urban Drainage Research Centre (REDAC) and Sarawak Rivers Board (SRB) and their co-organizers such as the Department of Irrigation and Drainage (DID) Malaysia, and the others, for their enthusiasm to support this conference as a way of awareness and sharing experience at the national and international level.

Publications:

ISBN 978-983-3067-18-3 (Abstract Book)

ISBN 978-983-3067-19-0 (CD-ROM)

ISBN 978-983-3067-28-2 (Proceedings)

ISSN 1741-7589 (Special Issue Rivers'07, Water Management, Institution of Civil Engineers, Vol. 162)





**3rd International Conference on Managing Rivers in the 21st Century :
Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity**
Date: 6th - 9th December 2011
Venue: Penang



Weather and climate are among the foremost factors that determine how a society develops in a geographical region. During the last thirty years of hydro-climate studies, two by products of men's industrial and agriculture activities were recognized as potential causes for the climate change in the form of global warming. The forecast of the global heat release for the year 2075 is about 0.1% of the incoming solar energy.

However, at regional scale the heat released over a geographical region through the energy consumption in 2075 could be about 2.6% of the incoming solar energy. This is an amount which can have significant effect on climate warming over a geographical region, such as Asia Pacific, with serious hydrological consequences as to rainfall, temperature and stream flow magnitudes. In this connection, the Local Organizing Committee would like to draw attention of the participants to the seriousness of

potential problem for Asia Pacific and worldwide due to the long-term climate and hydrologic impact of global warming and find sustainable solutions in relation to flooding, river pollution and water scarcity.

The Rivers 2011 conference is the third of a series of triennial International Conference on Managing Rivers in the 21st Century. The organizer aimed to draw attention of the participants to the seriousness of potential problem for Asia Pacific and worldwide due to the long-term climate and hydrologic impact of global warming and find sustainable solutions in relation to flooding, river pollution and water scarcity.

This conference is supported by government agencies and research institutions at national level and a prestigious international professional society. These include the International Association for Hydro-Environment Engineering and Research (IAHR), National Water Service Commissions (SPAN), Department of Irrigation and Drainage (DID) Malaysia, Department of Environment (DOE) Malaysia, National Hydraulic Research Institute of Malaysia (NAHRIM), Forest Research Institute Malaysia (FRIM), Humid Tropics Centre (HTC), Institute for Environment and Development (LESTARI), Kuala Lumpur Infrastructure University College (KLIUC), Universiti Teknologi MARA (UiTM), Universiti Putra Malaysia (UPM), Malaysian National Committee on Irrigation and Drainage (MANCID) and Water Watch Penang (WWP).

The conference was officiated by the Director-General of Department of Irrigation and Drainage (DID) Malaysia, Dato' Ir. Hj. Ahmad Husaini. Seven keynote speakers who are renowned experts from national and international levels namely Dato' Ir. Hj. Ahmad Husaini, Prof. Roger A. Falconer (Cardiff University, UK), Prof. Roslan Zainal Abidin (Kuala Lumpur Infrastructure University College, Malaysia), Prof. Makarand Chintamani Deo (Indian Institute of Technology, Bombay, India), Prof. Shabaz Khan (UNESCO-IHP HELP, Paris), Prof. Dr. Van-Thanh-Van Nguyen, (McGill University, Canada) and Prof. Nor Azazi Zakaria (Universiti Sains Malaysia), delivered their keynote addresses over the course of the conference covering the subjects of Integrated Water Resources Management (IWRM), Environmental Hydraulics, River Bank Erosion Risk, Data Mining in Hydrology and Hydraulics and Flood Forecasting and Flood Risk Management and Mitigation.

Technical papers for this conference was divided into 11 major topics: Integrated Water Resources Management (18 papers), Eco and Environmental-Hydraulics (14 papers), Innovative Urban Drainage Management (8 papers), Data Mining in Hydraulics and Hydrology (8 papers), Flood Management and Hydroinformatics (15 papers), Floodplain, River and Estuarine Rehabilitation (9 papers), Flood Forecasting and Flood Risk Management / Mitigation (8 papers), Water Quality Treatment (9 papers), Watershed Land Use Planning and Management (3 papers), Soil Erosion and Sedimentation (14 papers) and Water-Related Hazard and Disaster (4 papers). These papers were presented by authors in 9 technical sessions whereby every two parallel sessions ran concurrently. Approximately 40% of the papers were from international participants whereas the rest 60% were from local participants including those from research institutions, NGOs and government agencies. The conference managed to attract about 200 participants from 17 countries. During the final day, technical visits to BIOECODS at USM engineering campus and River Penang Rehabilitation Plan. His Excellency the head of State of Penang officially brought the curtain down on the 4-day conference.

Publications:
ISBN 978-983-3067-35-0 (CD-ROM)

6.3 MAJOR EVENTS

National Launching of the Bio-Ecological Drainage System (BIOECODS)

Date: 4th February 2004

Venue: USM Engineering Campus

In 1999, a Memorandum of Understanding (MoU) of 3 years (October 1999 to September 2002) was signed between Department of Irrigation and Drainage Malaysia and Universiti Sains Malaysia to form a smart partnership in developing the fields of river engineering and urban drainage. Subsequently, REDAC was formed and the BIOECODS system was constructed in USM as the pilot project to showcase the implementation of DID's stormwater manual, MSMA. It was only appropriate that the event to mark the end of such successful partnership was the national launching of the BIOECODS system in engineering campus of USM. The BIOECODS system was launched by His Excellency the head of State of Penang, Tun Dato' Seri Utama (Dr.) Haji Abdul Rahman Haji Abbas on February 4, 2003. As a result of this successful partnership, an extension to the first MoU was signed between USM and DID during the same event. This was witnessed by His Excellency the Governor of Penang himself during the same event. This new MoU (October 2002 to September 2005) would see further research and development in the field of river engineering and urban drainage at REDAC. DID would gain capacity building opportunity through enrolment of their staff in postgraduate research programmes at USM.

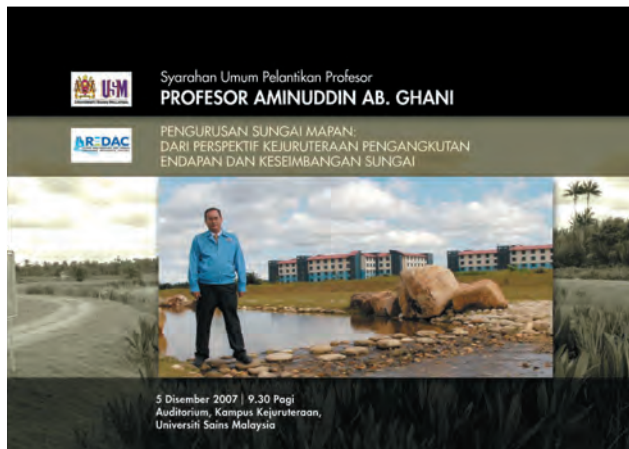




Inaugural Professorial Lecture: Prof. Nor Azazi Zakaria and Prof. Aminuddin Ab. Ghani

Date: 5th December 2007

Venue: Dewan Auditorium, USM Engineering Campus



In commemoration for their promotion to full professorship by Universiti Sains Malaysia, a simple yet significant ceremony was held on 5th December 2007 at the auditorium hall in the Engineering Campus of Universiti Sains Malaysia. Professor Nor Azazi Zakaria and Professor Aminuddin Ab. Ghani delivered their inaugural professorial lectures titled 'Sustainable Urban Drainage System: Solution for Flash Flood, River Pollution and Water Scarcity' and 'Sustainable River Management: From the Perspective of Sediment Transport Engineering and River Stability' respectively during this special event.

The event started at about 9.00am when guests and guests of honour started to arrive at the auditorium. They are greeted and welcomed by Prof Azazi, Prof Aminuddin and other REDAC staff. Among the guests of honour include Yang Berbahagia Dato' Professor Muhammad Idris Salleh, Deputy Vice Chancellor (Research and Innovation) of USM, representing the Vice Chancellor of USM, Yang Berbahagia Professor Lim Koon Ong, Deputy Vice Chancellor (Industry and Community Network), Yang Berbahagia Dato' Professor Ishak Tamby Kechik, former Vice Chancellor of USM, Yang Berusaha Azman Abdullah, Registrar of USM. There were about 500 guests who attended the event, consisting of USM staff, research collaborators and business partners from government and private sectors, as well as friends and families.

The lecture by Prof Azazi touched on the importance of Sustainable Urban Drainage System (SUDS), which is a long-term urban drainage design taking into account the aspects of environment and social requirements, apart from the conventional drainage requirements. This relatively new approach aimed to mimic natural flow regime of stormwater runoff, infiltration of water into adjacent ground and remove pollutants using natural means such as soil and vegetation. In his lecture, Prof Azazi introduced the Bio-ecological Drainage Systems (BIOECODS) pioneered by his research team. The BIOECODS is a stormwater management system which is environmental friendly and sustainable, having been fully comply with the design requirements of the Urban Stormwater Management Manual for Malaysia (MSMA). The BIOECODS, which is first constructed as a pilot project, was a product of smart partnership between the Department of Irrigation and Drainage and Universiti Sains Malaysia. He went on to present the performance and capability of the BIOECODS system in controlling runoff in quantity and quality through years of monitoring and analysis. Finally, Prof Azazi presented in brief, application of BIOECODS in other development sites, which include Forensic Ward of Hospital Bahagia, Tanjung Rambutan (Ipoh, Perak), Asrama Anak Yatim Majlis Agama Islam dan Adat Istiadat Melayu Kelantan (MAIK)(Kora Bharu, Kelantan), Klinik Kesihatan Jenis 2 Taiping (Taiping, Perak) and DID Mechanical Office (Ipoh, Perak).



Prof Aminuddin focused his lecture on the importance of understanding the process of sediment transport in rivers as this would significantly help to preserve equilibrium in natural rivers and the long term sustainability of any river rehabilitation works. According to him, the stability of a river is highly influence by four factors namely, discharge, river gradient, sediment characteristics, and sediment loading. Changes in any one of the factors could potentially disrupt the equilibrium state of a river, causing sedimentation or increase in discharge over short period (in other words, flood). Therefore, despite being a rapid growing country, Malaysia needs to be more respectful and careful in managing the equilibrium of her rivers to ensure any on-going development can be sustained without negative consequences and that rivers would continue to be part of our cultural heritage.

A simple exhibition was also put up during the event to showcase research works by the professors and REDAC. This includes journal publications, books and bulletin, reports for contractual research, proceedings of international conferences, poster any many more. The exhibition was aimed to share REDAC's findings and knowledge especially with non-academic guests who are interested in rivers and urban drains, as these systems are parts of their daily lives.





MANCID Student Programme
Date: 9th February 2011
Venue: USM Engineering Campus



The Malaysian National Committee on Irrigation and Drainage (MANCID) is an accredited Non-government Organization (BGO) under the Ministry of Agriculture and Agro-based Industries. In an effort to reach out and attract young professionals to join the organization, MANCID had launched the 'MANCID Student Programme'. The programme, aimed to encourage participation of university students in their activities on irrigation and drainage. Universiti Sains Malaysia was targeted as one of the universities on their campaign. REDAC provided technical assistant to organise an introductory briefing by MANCID to the campus crowd. About 250 participants, consisting of students, lecturers and staff, attended the briefing held at the Auditorium in USM engineering campus. They were briefed on the history of irrigation and drainage development in the country, the role of engineers in this fields. Also, the audience were introduced to MANCID, the functions, events and benefits of being a MANCID member.



7.0



**INTERNATIONAL
AND NATIONAL
VISITORS TO REDAC**



Professor Roberto Mayerle & Professor
C. Nalluri, Kiel, University of Germany
(1st August 2002)



Professor Pierre Y. Julien, Colorado
State University, USA
(10th August 2002)



Professor Roger A Falconer, Cardiff
University, Wales, United Kingdom
(13th August 2002)



Dr. Emma Harris, Cardiff University,
Wales, United Kingdom
(18th December 2002)



Prince of Songkla University, Thailand
(17th March 2004)



National Launching of the BIOECODS
(4th February 2003)



Ipoh City Council
(24th June 2004)



Participants from Rivers'04
(30th November-2nd December 2004)



Urban Stormwater Management Short
Course (USWM)
(30th November-2nd December 2004)



Penang State Secretariat Office
(26th February 2005)



Atlantis Corporation Pty Ltd, Australia
(23rd August 2005)



Penang Public Works Department
(27th May 2005)



Urban Stormwater Management Short Course (USWM-2)
(26th-28th April 2005)



Urban Stormwater Management Short Course (USWM-3)
(6th-8th September 2005)



Department of Fisheries of Penang
(22nd September 2005)



Integrated River Basin Management (IRBM), Kedah
(24th November 2005)



Department of Irrigation and Drainage
(JPS) Malaysia
(22nd December 2005)



Universiti Malaysia Pahang (UMP)
(25th March 2006)



Professor Pierre Y. Julien, Colorado
State University, USA
(27th May 2005 & 16th May 2006)



Department of Irrigation and Drainage Malaysia & Malaysia
Institute of Nuclear Technology (MINT)
(4th April 2006)



Universiti Tun Hussein Onn Malaysia
(13th June 2006)



Public Works Department (Cawangan
Persekutuan), Kuala Lumpur
(10th July 2006)



Department of Irrigation and
Drainage, Kubang Pasu / Padang
Terap, Jitra Kedah
(10th July 2006)



Urban Stormwater Management Short
Course (USWM-4)
(12th-14th September 2006)



Datuk Seri Azmi Khalid, Ministry of
Natural Resources and Environment
(NRE)
(12th October 2006)



University's Board of Directors
(20th November 2006)



Prime Minister's Economic Plan
Unit (EPU)
(7th December 2006)



Profesor Larry A. Roesner, Colorado State University, USA
(8th January 2007)



Stormwater Quality Management Seminar (USWM-5)
(9th-11th January 2007)



Malaysian Flood Commission
(12th February 2007)



Politeknik Kota, Melaka
(19th April 2007)



National Service Training Programme (PLKN) 2nd Group, Kem Jiwa Murni Semanggol, Perak
(28th April 2007)



Department of Irrigation and Drainage, Sarawak and Ministry of Tourism and Heritage Sarawak
(20th June 2007)



Jelutong Development Sdn. Bhd. (IJM)
(29th June 2007)



Universiti Malaysia Pahang (UMP)
(25th August 2007)



School of Housing, Building & Planning, Universiti Sains Malaysia (Engineering Studio 200 & 300)
(10th September 2007)



Universiti Malaysia Terengganu (UMT)
(14th September 2007)



National Service Training Programme (PLKN), 3rd Group, Kem Jiwa Murni Semanggol, Perak
(25th August 2007)



Science Officer Society USM
(28th November 2007)



Coordinator of Healthy Campus (USM)
(31st October 2007)



National Service Training Programme (PLKN), 3rd Group, Kem Jiwa Murni Semanggol, Perak
(1st Mac 2008)



Postgraduate Student, School of Housing, Building & Planning, USM
(11th Mac 2008)



Dedicated Local Council for Kulim Hi-Tech Park
(13th Mac 2008)



Development Department, Universiti Utara Malaysia (UUM)
(23rd April 2008)



Professor Joseph Lee HeungWing, University of Hong Kong
(29th July 2008)



LESTARI's Design Group, Universiti Kebangsaan Malaysia (UKM)
(31st October 2008)



Participants from International Course on Flood Mitigation and Stormwater Management (24th October 2008)



Politeknik Sultan Abdul Halim Mu'adzam Shah (POLIMAS) (7th May 2009)



International Workshop on Urban Storm Water Management (USWM): Malaysian Experiences (1st - 2nd July 2009)



Tasik Chini Research Centre (PPTC), UKM (4th September 2009)



Prof. Donald DeAngeles University of Miami, USA (6th October 2009)



Participants from 3rd International Course On Flood Mitigation and Stormwater Management (19th October 2009)



Department of Architecture, Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia (UKM) (22nd January 2010)



Prof. Dr. Ing. Silke Wieprecht, Institute of Hydraulic Engineering (IWS), University of Stuttgart, Germany (4th January 2010)



Selangor State Government (9th February 2010)



Academic Visit Program of POLISA's Civil Engineering Student (14th April 2010)



Malaysian Institute of Road
Safety Research (MIROS)
(30th September 2010)



Participants from Urban Stormwater Water Management Seminar
(USWM-9)
(8th - 9th December 2010)



Participants from 4th International
Course On Flood Mitigation and
Stormwater Management
(19th October 2010)



School of Engineering and Resources
Management,
Walailak University, Thailand
(29th September 2011)



Professor Mohamed S, Ghidaoui
The Hong Kong University of Science
& Technology (HKUST)
(25th January 2011)



Professor Masazumi Ao, International College of Arts and Sciences,
Global Cooperation Institute for Sustainable Cities,
Yokohama City University, Japan
(7th September 2011)



Department of Irrigation and Drainage (DID) Penang,
Malaysia
(16th November 2011)



National Landscape Department, Ministry of Housing and Local Government (MHLG)
(15th November 2011)

8.0



RESEARCH PUBLICATIONS

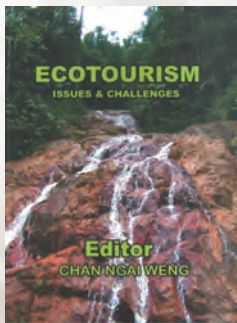
8.1 | RESEARCH BOOKS/ CHAPTERS IN BOOKS



Mohd Sidek, L., Zakaria, N.A., Ab. Ghani, A., & Abdullah, R. (2002). Alternative Solutions to Conventional Drainage Systems using Bio-Ecological Drainage Systems: Design and Concepts, Part 1, *Bulletin Board of Engineers Malaysia*, Vol. 15, No.2, pp. 46-51, June. ISSN: 0128-4347



Mohd Sidek, L., Zakaria, N.A., Ab. Ghani, A., & Abdullah, R. (2003). Alternative Solutions to Conventional Drainage Systems using Bio-Ecological Drainage Systems: Design and Concepts, Part 2, *Bulletin Board of Engineers Malaysia*, Vol. 15, No. 3, pp. 47-52, September. ISSN: 0128-4347



Zakaria, N.A., Ab. Ghani, A., Kung, H.T and Chan, N.W. (2004). Chapter 14: Using Rivers for Ecotourism. In: Chan, N.W, *Ecotourism: Issues and Challenges*. Penang: School of Humanities, Universiti Sains Malaysia, 119-128. ISBN 983-42017-0-2.



Zakaria, N.A., Ab. Ghani, A, Abdullah, R., NMohd. Sidek, L.. & Ainan, A. (2004). *Bio-Ecological Drainage System (BIOECODS): Selected Publications*, 144 pp. ISBN: 983-3067-07-7



Ab. Ghani, A. & Zakaria, N.A. (2005). Case Study: The Bio-Ecological Drainage System Project, Malaysia, in: J. Parkinson and O. Mark, *Urban Storm water Management in Developing Countries*, pp. 116-120, IWA. ISBN: 1-843390-57-4



Zakaria, N.A. (2008). *Sustainable Urban Drainage System: Global Solutions of Flash Flood, River Pollution and Water Scarcity*, USM Professorial Talk Series, 90 pp. ISBN: 978-983-861-352-1



Ab. Ghani, A. (2008). *Sustainable River Management: from the Sediment Transport and River Equilibrium Perspectives*, USM Professorial Talk Series, 52 pp. ISBN: 978-983-861-382-8



Chang, C.K. and Ab. Ghani, A. (2011). *Sediment Transport in Kulim River, Kedah, Malaysia*, *Sediment Transport*, Silvia Susana Ginsberg (Ed.), InTech. ISBN: 978-953-307-189-3



8.2 | INTERNATIONAL JOURNALS

Publication:

Nalluri, C., Ab. Ghani, A. & El-Zaemey, K.S. (1994). Sediment Transport Over Deposited Beds in Sewers. *Journal of Water Science and Technology*, IWA, Vol. 29, No.1-2, pp. 125-133, ISSN: 0273-1223.

Abstract

This paper is based on an extensive experimental investigation of bedload transport of noncohesive sediments at 'limit deposition' in channels of circular and rectangular cross-section. The effect of permanent deposits on the invert of pipe channels on sediment carrying capacity and hydraulic resistance to flow is investigated. The sediment transport data from rectangular and pipe channels led to the development of empirical equations with high correlation coefficients. These equations showed the possibilities of their validity for either channel shape with the incorporation of appropriate shape parameters.

Keywords: Bedload transport, Deposited beds, Design criteria, Limit deposition, Sediments, Sewers.

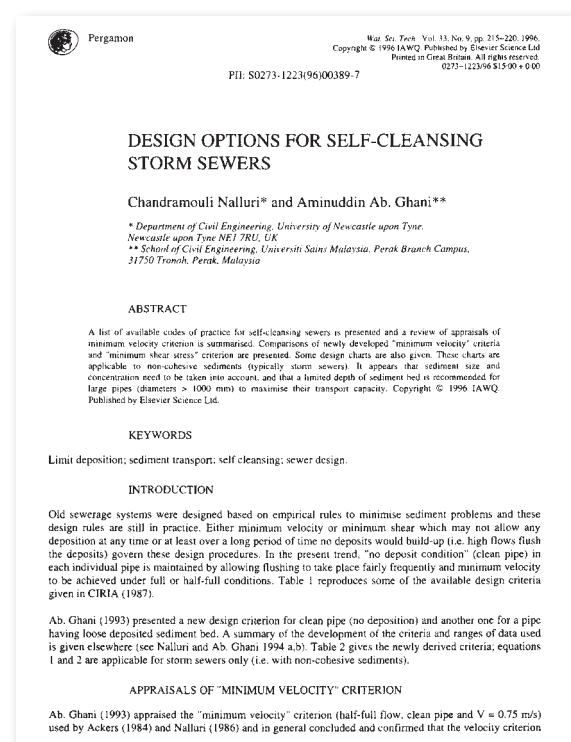
Publication:

Nalluri, C., Ab. Ghani, A. & El-Zaemey, K.S. (1994). Sediment Transport Over Deposited Beds in Sewers. *Journal of Water Science and Technology*, IWA, Vol. 29, No.1-2, pp. 125-133, ISSN: 0273-1223.

Abstract

A list of available codes of practice for self-cleansing sewers is presented and a review of appraisals of minimum velocity criterion is summarised. Comparisons of newly developed 'minimum velocity' criteria and 'minimum shear stress' criterion are presented. Some design charts are also given. These charts are applicable to non-cohesive sediments (typically storm sewers). It appears that sediment size and concentration need to be taken into account, and that a limited depth of sediment bed is recommended for large pipes (diameters > 1000 mm) to maximise their transport capacity.

Keywords: Limit deposition, Sediment transport, Self cleansing, Sewer design.



Publication:

Ab. Ghani, A., Zakaria, N.A., Kassim, M., & Ahmad Nasir, B. (2000). Sediment Size Characteristics of Urban Drains in Malaysian Cities. *Journal of Urban Water, Elsevier Science*, Vol. 2, No.4, pp. 335-341. ISSN: 1462-0758, DOI:10.1016/S1462-0758(01)00013-9.

Abstract

The existing conventional drainage systems in cities throughout Malaysia have been built mainly to cater for the increase in surface runoff due to rapid development that occurs in the city borders. The drainage system is normally made up of open rigid concrete drain channels susceptible to maintenance problems such as sediment deposition, litter and utility pipes crossing. This paper highlights the results of surveys carried out to determine the sediment size characteristics in urban drains of five cities in Malaysia. A preliminary result from a sediment profile observation at Sungai Raja drainage system, Alor Setar is also described to establish the effect of drain size and slope on deposition trend

Keywords: Conventional drainage system, deposition, Malaysia, Sediment size, Urban drains.

Publication:

Ariffin, J., Ab. Ghani, A., Zakaria, N.A., Yahya, A.S. & Abdul-Talib, S. (2002). Transverse Velocity Distribution in Relation to Bed Load Movement in Natural Channels. *Water Studies*, Vol 10, pp. 183-190. ISBN: 1853128147. DOI: 10.2495/HY020181.

Abstract

The transverse velocity distribution in a plane normal to the direction of flow with respect to bed load movement is analysed. There are limited studies on the transverse velocity profiles in natural channels with B/y_0 aspect ratio greater than 10. The findings are based on observations under field conditions in two rivers namely Sungai Lui and Sungai Semenyih. In this paper, results of field experiments on the effects of velocity to bed load profile were examined. The findings indicated that velocity was not the only determining factor to the change in bed load profile. Other contributing factors responsible for the change include bed slope and composition of the bed load.

Keywords: Algorithms, Erosion, Mathematical models, Rivers, Sediment transport, Shear stress, Turbulence, Viscosity.



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ISBN 1-85312-912-7

Transverse velocity distribution in relation to bed load movement in natural channels

J. Ariffin¹, A. Ab. Ghani¹, N. A. Zakaria¹, A. S. Yahya¹ & S. Abdul-Talib²

¹River Engineering and Urban Drainage Research Centre (REDAC), University Science Malaysia, Malaysia.

²Faculty of Civil Engineering, Universiti Teknologi MARA, Malaysia.

Abstract

The transverse velocity distribution in a plane normal to the direction of flow with respect to bed load movement is analysed. There are limited studies on the transverse velocity profiles in natural channels with B/y_0 aspect ratio greater than 10. The findings are based on observations under field conditions in two rivers namely Sungai Lui and Sungai Semenyih. In this paper, results of field experiments on the effects of velocity to bed load profile were examined. The findings indicated that velocity was not the only determining factor to the change in bed load profile. Other contributing factors responsible for the change include bed slope and composition of the bed load.

1 Introduction

Natural channels are known to change their slopes, widths, depths and velocities with space and time. The velocity of flow is largely dependent on the geometry of the channel which undergo deformation continuously due to the processes of erosion and deposition. An accurate estimation of the amount of sediment and bed roughness rely on a good understanding and ability to simulate the velocity profile.

Transverse velocity distribution is considered as one of the determining factors in predicting the movement of bed load. Several experimental investigations have been done using flumes where bed shear stresses are constant and the velocity profiles estimated under controlled conditions [1,2,3].

Publication:

Sinnakaudan, S.K., Ab. Ghani, A., Ahmad, M.S.S. & Zakaria, N.A. (2003). Flood Risk Mapping for Pari River Incorporating Sediment Transport. *Journal of Environmental Modelling and Software*, Elsevier Science, Vol. 18, No. 2, pp. 119-130. ISSN: 1364-8152, DOI: 10.1016/S1364-8152(02)00068-3.

Abstract

Geographic Information Systems (GIS) are an efficient and interactive spatial decision support tool for flood risk analysis. This paper describes the development of ArcView GIS extension- namely AVHEC-6.avx – to integrate the HEC-6 hydraulic model within GIS environment. The extension was written in an Avenue Script language and Dialog Designer with a series of 'point and click' options. It has the capability of analyzing the computed water surface profiles generated from HEC-6 model and producing a related flood map for the Pari River in the ArcView GIS. The user-friendly menu interface guides the user to understand, visualize, build query, conduct repetitions and multiple analytical tasks with HEC-6 outputs. The flood risk model was tested using the hydraulic and hydrological data from the Pari River catchment area. The required sediment input parameters were obtained from field sampling. The results of this study clearly show that GIS provides an effective environment for flood risk analysis and mapping. The present study only concentrates on the flood risk within the boundary of the bunds.

Keywords: GIS, River, Flood Risk, Sediment Transport, System Integration.

Publication:

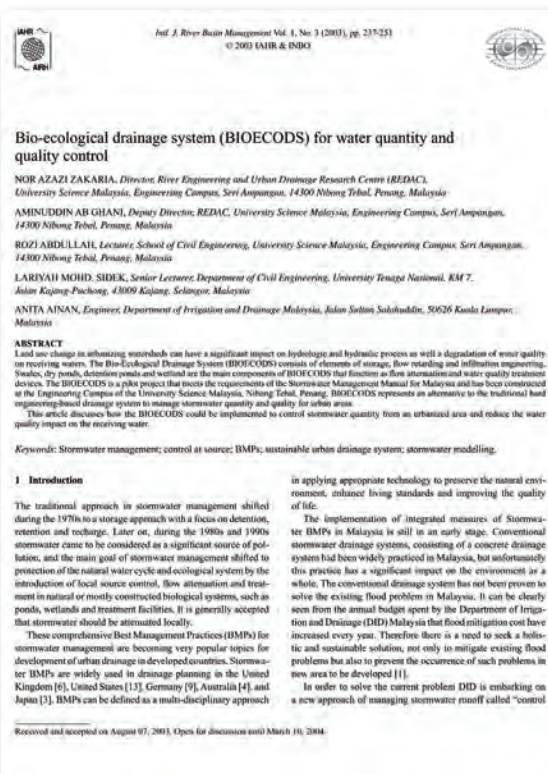
Zakaria, N.A., Ab. Ghani, A., Abdullah, R., Mohd Sidek, L. & Ainan, A. (2003). Bio-Ecological Drainage System (BIOECODS) for Water Quantity and Quality Control. *International Journal of River Basin Management*, IAHR & INBO, Vol. 1, No. 3, pp. 237-251. ISSN: 1571-5124, DOI: 10.1080/15715124.2003.9635210.

Abstract

Land use change in urbanizing watersheds can have a significant impact on hydrologic and hydraulic process as well as degradation of water quality on receiving waters. The Bio-Ecological Drainage System (BIOECODS) consists of elements of storage, flow retarding and infiltration engineering. Swales, dry ponds, detention ponds and wetland are the main components of BIOECODS that function as flow attenuation and water quality treatment devices. The BIOECODS is a pilot project that meets the requirements of the Stormwater Management Manual for Malaysia and has been constructed engineering-based drainage system to manage stormwater quantity and quality for urban areas.

This article discusses how the BIOECODS could be implemented to control stormwater quantity from an urbanized area and reduce the water quality impact on the receiving water.

Keywords: Stormwater management, control at source, BMP's, sustainable urban drainage system, stormwater modelling.



Publication:

Chang, C. K., Ab. Ghani, A., Zakaria, N. A., Abu Hasan, Z. & Abdullah, R. (2005). Sediment Transport Equation Assessment for Selected Rivers in Malaysia. Special Issue Rivers'04, *International Journal of River Basin Management*, IAHR & INBO, Vol. 3, No. 3, pp. 203-208. ISSN: 1571-5124, DOI:10.1080/15715124.2005.9635259.

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.

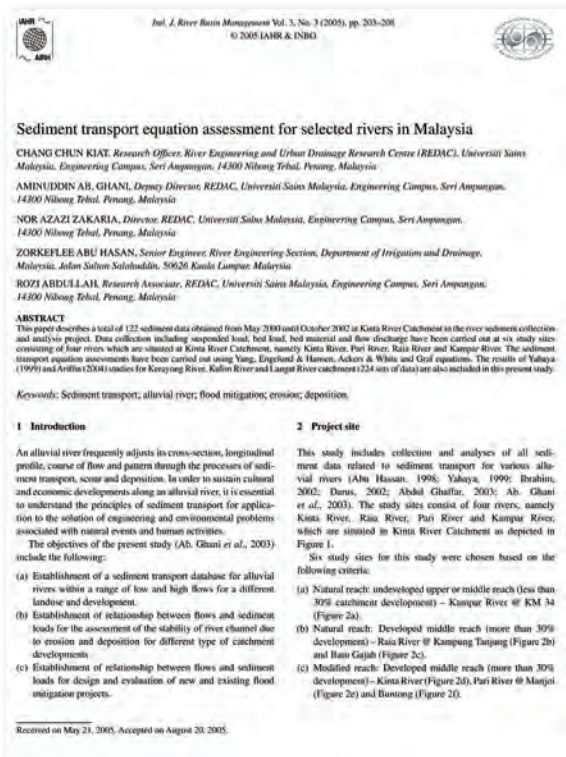
Publication:

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. Special Issue Rivers'04, *International Journal of River Basin Management*, IAHR & INBO, Vol. 3, No. 3, pp. 215-221. ISSN:1571-5124, DOI:10.1080/15715124.2005.9635261.

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.



Publication:

Sinnakaudan, S. K., Ab. Ghani, A., Ahmad, M. S. S., & Zakaria, N.A. (2006). Multiple Linear Regression Model for Total Bed Material Load Prediction. *Journal of Hydraulic Engineering*, ASCE. Vol. 132, No. 5, pp. 521-528. ISSN: 0733-9429, DOI: 10.1061/(ASCE)0733-9429(2006)132:5(521).

Abstract

A new total bed material load equation that is applicable for rivers in Malaysia was developed using multiple linear regression analyses. A total of 346 hydraulic and sediment data were collected from nine natural and channelized rivers having diverse catchment characteristics in Malaysia. The governing parameters were carefully selected based on literature survey and field experiments, examined and grouped into five categories namely mobility, transport, sediment, shape, and flow resistance parameters. The most influential parameters from each group were selected by using all possible regression model method. The suitable model selection criteria namely the R-square, adjusted R-square, mean square error, and Mallow's C_p statistics were employed. The accuracy of the derived model is determined using the discrepancy ratio, which is a ratio of the calculated values to the measured values. The best performing models that give the highest percentage of prediction from the validation data were chosen. In general, the newly derived model is best suited for rivers with uniform sediment size distribution with a d_{50} value within the range of 0.37–4.0 mm and performs better than the commonly used Graf, Yang, and Ackers–White total bed material load equations.

Keywords: Sediment transport, Rivers, Regression models, Sediment load, Predictions, Bed materials.

Publication:

Ab. Ghani, A., Zakaria, N.A., Chang, C.K., Ariffin, J., Abu Hasan, Z. & Abdul Ghaffar, A. B. (2007). Revised Equations for Manning's Coefficient for Sand-Bed Rivers. *International Journal of River Basin Management*, IAHR & INBO, Vol. 5, No. 4, pp. 329-346. ISSN: 1571-5124, DOI:10.1080/15715124.2007.9635331.

Abstract

The procedure for selecting values of Manning n is subjective and requires judgment and skill which are developed primarily through experience. Government agencies and private sectors in developed nations such as the USA are still doing research on predicting n values for rivers. Since flow and boundary roughness vary with river conditions, such research is therefore pertinent for rivers in Malaysia where floods are one of primary concerns. Research on Manning n value was started by River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia (USM) since 2000 at the Kinta River catchment. Further data collections were later made at two other major rivers i.e. Langat River and Kulim River. Two new equations are proposed for determining Manning n for sand-bed rivers in Malaysia based on 163 data collected from these three rivers. On average, both equations have an error less than 10% in predicting flow discharge for all 163 data.

Keywords: Flood mitigation, sand-bed rivers, flow resistance, Manning n .

Multiple Linear Regression Model for Total Bed Material Load Prediction

S. K. Sinnakaudan¹; A. Ab Ghani²; M. S. S. Ahmad³; and N. A. Zakaria⁴

Abstract: A new total bed material load equation that is applicable for rivers in Malaysia was developed using multiple linear regression analyses. A total of 346 hydraulic and sediment data were collected from nine natural and channelized rivers having diverse catchment characteristics in Malaysia. The governing parameters were carefully selected based on literature survey and field experiments, examined and grouped into five categories namely mobility, transport, sediment, shape, and flow resistance parameters. The most influential parameters from each group were selected by using all possible regression model method. The suitable model selection criteria namely the R-square, adjusted R-square, mean square error, and Mallow's C_p statistics were employed. The accuracy of the derived model is determined using the discrepancy ratio, which is a ratio of the calculated values to the measured values. The best performing models that give the highest percentage of prediction from the validation data were chosen. In general, the newly derived model is best suited for rivers with uniform sediment size distribution with a d_{50} value within the range of 0.37–4.0 mm and performs better than the commonly used Graf, Yang, and Ackers–White total bed material load equations.

DOI: 10.1061/(ASCE)0733-9429(2006)132:5(521)

CE Database subject headings: Sediment transport; Rivers; Regression models; Sediment load; Predictions; Bed materials.

Introduction

Reliable and quantitative estimates of the bed aggradation or degradation are very important in river engineering and water management projects as well as accurately predicting the water surface elevations during floods in estimating flood related damage. A number of sediment transport studies have been conducted in channels and flumes to develop analytical solutions for simplifying the governing equations describing complex phenomenon of the aggradation and degradation processes (Ab. Ghani 1993; Karim 1998; Molinas and Wu 2001; Sinnakaudan 2003). Researchers have separately treated the suspended load and the bed load calculation. However recent literature shows that total sediment load (or bed material load) equations are much preferred and researchers are now moving toward employing more complex

analytical methods such as the artificial neural network (Nagy et al. 2002).

Good appraisals of available total sediment load equations and their performance were given by White et al. (1975), Brownlie (1981), Yang and Molinas (1982), Shen and Hung (1983), Rappelt (1990), Nakato (1990), Wu et al. (1993), and Nagy et al. (2002). Some of the available total bed material load equations are developed by Graf (1971), Ackers and White (1973), Van Rijn (1984a,b,c), and Karim (1998). The existing equations are mostly developed based on flume data in western countries including America and Western Europe. However not all of these equations are widely used or evaluated in other parts of the world. Several equations such as Ackers–White (1973) have been incorporated into current loose boundary models such as HEC-6 (USACE 1993) and the Graf (1971) equation is available in *Fluvial-2* (Chang 1993) to simulate the sediment transporting capability of rivers.

Since the 1990s, few attempts have been made to evaluate the available equations for Malaysian conditions and are mostly cited in Ariffin et al. (2002) and Sinnakaudan et al. (2003). The Malaysian river data, against which these equations were checked, consists of field experiments in natural and channelized watercourses that were recently compiled by the Department of Irrigation and Drainage (DID) Malaysia (DID 2003). However, most of the developed equations rely heavily on flume data as well as river data (Brownlie 1981), which are not native to this region and have significant differences in hydraulic and sediment characteristics. The uncertainties of the usage of the existing equation for Malaysian river conditions are further proven by analysis of the discrepancy ratio, which is a ratio between predicted versus measured total bed material load values. Any equation is considered suitable if it falls within the acceptable range of 0.5–2.0. The performance test on Graf (1971) and Ackers and White (1973) as summarized in Table 1 indicates that these equations have a predictive power of less than 40%.

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Revised equations for Manning's coefficient for sand-bed rivers

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ABSTRACT

The procedure for selecting values of Manning n is subjective and requires judgment and skill which are developed primarily through experience. Government agencies and private sectors in developed nations such as the USA are still doing research on predicting n values for rivers. Since flow and boundary roughness vary with river conditions, such research is therefore pertinent for rivers in Malaysia where floods are one of primary concerns. Research on Manning n value was started by River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia (USM) since 2000 at the Kinta River catchment. Further data collections were later made at two other major rivers i.e. Langat River and Kulim River. Two new equations are proposed for determining Manning n for sand-bed rivers in Malaysia based on 163 data collected from these three rivers. On average, both equations have an error less than 10% in predicting flow discharge for all 163 data.

Keywords: Flood mitigation; sand-bed rivers; flow resistance; Manning n .

1 Introduction

Southeast Asia has long experienced a monsoon climate with dry and wet seasons. With mean annual rainfall precipitation locally in excess of 5,000 mm, the very intense rainstorms in the steep mountains of Malaysia have caused frequent and devastating floods in the last five years especially in 2003 (Northern states of Kelah, Penang and Perlis) and 2006 (Southern states of Malacca, Johor and Pahang). Urbanization also exacerbates the problem and increases river discharge due to increase in impervious areas of the upper watershed.

The protection of the communities against floods has become the primary concern of the Malaysian government. One of the methods commonly used to mitigate the floods is by constructing levees or bunds along the lowland areas surrounding river channels. A recent example of the flood mitigation project involves the Muda River, Kelah (Julien et al. 2006) that highlights several

important points in the design of flood remediation countermeasures against intense and regular flooding during the monsoons of South-East Asia. The study reach covers 41.2 km between the river mouth and Ladang Victoria (Figure 1) which was the area that was heavily flooded in 2003. The hydraulic analysis using HEC-RAS model of the existing river system in the study area was carried out to provide information on the variations of river water levels, discharges, and velocities during flood events. Due to lack of field measurement data to determine suitable values of Manning n , different values were tried during the calibration of the HEC-RAS model. The best results were obtained with Manning n of 0.030 and 0.050 for the main channel and floodplains respectively (Figure 2). Water level records at three locations (Ladang Victoria, Bumbong Lima and River Mouth) during the 2003 flood were used to check the predicted water level by the HEC-RAS model. The model results are considered sufficiently accurate for the determination of levee heights. This study by

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Publication:

Lai, S.H., Bessaih, N., Puong, L.L., Ab. Ghani, A., Zakaria, N.A & Mah, D.Y.S. (2007). Determination of Apparent and Composite Friction Factors for Flooded Equatorial Natural Rivers. *International Journal of River Basin Management*, IAHR & INBO. Vol. 6, No. 1, pp. 3-12. ISSN: 1571-5124, DOI:10.1080/15715124.2008.9635332.

Abstract

This paper presents results, calculated from field measurements taken in several frequently flooded natural rivers, which include D and R relationships, variation of flow resistance with depth of flow, the apparent friction factor, and the composite friction factor for flooded natural rivers. The results obtained have shown the complexity of flow resistance in natural rivers due to the interaction between the main channel and floodplain flow. The interaction has given rise to a pair of apparent shear stresses at the interface region, which can significantly reduce the discharge capacity of the rivers. The apparent shear was quantified in terms of an apparent friction factor, f_a , and it was found that the apparent shear stress is many times greater than the averaged boundary shear stress of the rivers. Based on the averaged boundary shear stress and apparent shear stress, the composite (actual) friction factor for the rivers can be estimated accurately ($R^2 = 0.99$) using a statistical method that had been derived.

Keywords: Flow resistance, friction factor, momentum transfer, natural river, overbank flow.

Publication:

Lai, S.H., N.A. Bessaih, Ab. Ghani, A., Zakaria, N.A., Law, P.L. & Ma, D.Y.S. (2007). Discharge Estimation for Equatorial Natural Rivers with Overbank Flow. *International Journal of River Basin Management*, IAHR & INBO. Vol. 6, No. 1, pp. 13-21. ISSN: 15715124, DOI:10.1080/15715124.2008.9635333.

Abstract

The estimation of discharge capacity in river channels is complicated by variations in geometry and boundary roughness. Estimating flood flows is particularly difficult because of compound cross-sectional geometries and because of the difficulties of flow gauging. Results are presented of a field study including the stage-discharge relationships and surface roughness in term of the Darcy-Weisbach friction factor, f_a for several frequently flooded equatorial natural rivers. Equations are presented giving the apparent shear force acting on the vertical interface between the main channel and floodplain. The resulted apparent friction factor, f_a is shown to increase rapidly for low relative depth. A method for predicting the discharge of overbank flow of natural rivers is then presented, by means of a composite friction, f_c , which represents the actual resistance to flow due to the averaged boundary shear force and the apparent shear force. Equations are also presented giving the composite friction factor from easily calculated parameters for overbank flow of natural rivers. The results obtained using the methods proposed show that a significant improvement has been achieved compare to the discharge obtained using traditional methods, with an averaged error of 2.7%.

Keywords: Discharge estimation, flow resistance, friction factor, momentum transfer, natural river, overbank flow.



Publication:

Azmathullah, H.Md., Deo, M.C. & Deolalikar, P.B. (2007). Alternative Neural Networks to Estimate the Scour Below Spillways. *Advances in Engineering Software*. Vol. 39, No. 8, pp. 689-698. ISSN: 0965-9978, DOI: 10.1016/j.advengsoft.2007.07.004.

Abstract

Artificial neural networks (ANN's) are associated with difficulties like lack of success in a given problem and unpredictable level of accuracy that could be achieved. In every new application it therefore becomes necessary to check their usefulness vis-à-vis the traditional methods and also to ascertain their performance by trying out different combinations of network architectures and learning schemes. The present study was oriented in this direction and it pertained to the problem of scour depth prediction for ski-jump type of spillways. It evaluates performance of different network configurations and learning mechanisms. The network architectures considered are the usual feed forward back propagation trained using the standard error back propagation as well as the cascade correlation training schemes, relatively less used configurations of radial basis function and adaptive neuro-fuzzy inference system. The network inputs were characteristic head and discharge intensity over the spillways while the output was the predicted scour depth at downstream of the bucket. The performance of different schemes was tested using error criteria of correlation coefficient, average error, average absolute deviation, and mean square error. It was found that the traditional formulae of Veronese, Wu, Martins and Incy as well as a new regression formula derived by authors failed to predict the scour depths satisfactorily and that the neuro-fuzzy scheme emerged as the most satisfactory one for the problem under consideration. This study showed that the traditional equation-based methods of predicting design scour downstream of a ski-jump bucket could better be replaced by one of the soft computing schemes.

Keywords: Ski-jump scour, ANN, ANFIS, RBF, Error criteria, Scour depths.

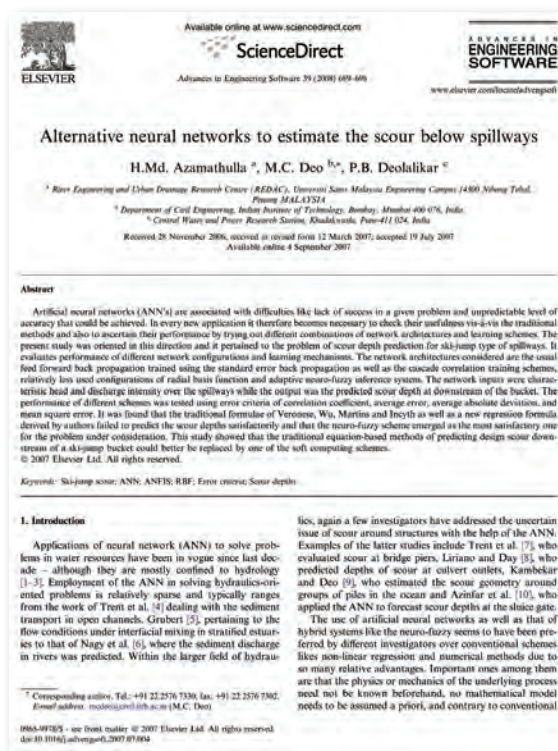
Publication:

Ab. Ghani, A., Zakaria, N.A. & Kassim, M. (2008). Sediment Deposition in a Rigid Monsoon Drain. *International Journal of River Basin Management*, IAHR & INBO. Vol. 6, No. 1, pp. 23-30. ISSN: 1571-5124, DOI:10.1080/15715124.2008.9635334.

Abstract

Field data collections to study the physical sediment characteristics and trends of sediment deposition were carried out at Raja River monsoon drain made up of concrete channels for the period of 2000 and 2001. Assessments of the existing incipient motion equations developed from experimental works were made using the measured field data. The results show that equations by Novak & Nalluri (1975), El-Zamey (1991) and Ab. Ghani *et al.* (1999) are able to predict satisfactorily the sediment deposition in rigid channel.

Keywords: Incipient motion, sediment deposits, rigid channel, storm drains.



Publication:

Lai, S.H., Bessaih, N., Law, P.L., Ab. Ghani, A., Zakaria, N.A. & Mah, D.Y.S. (2008). A study of hydraulic characteristics for flow in equatorial rivers. *International Journal of River Basin Management*, IAHR, INBO & IAHS, Vol. 6, No.3, pp. 213-223. ISSN 1571-5124, DOI:10.1080/15715124.2008.9635349.

Abstract

This paper presents the results obtained from field measurements taken in several frequently flooded equatorial rivers, including velocity distributions, stage discharge relationships, roughness behaviours and discharge estimation. These have illustrated the large difference in velocity between the main channel and floodplain under flood conditions, and the effects of momentum transfer between deep and shallow flow, which include reduction in main channel velocity and discharge capacity, leading to a reduction in compound section capacity at depth above bankfull. Another significant characteristic that has been found is that the floodplain regions behave as storage reservoirs ($V = 0$ m/s) in most cases due to high resistance of long and thick grasses along the flood plains ($n = 0.07-0.1$). Flow resistance relationships have been presented in terms of Manning's coefficient and Darcy-Weisbach friction factor, showing the complex nature of flow resistance in the rivers and further explaining the danger inherent in the conventional practices of extrapolating inbank data for the analysis of overbank flows. Results for discharge estimation have been shown for comparison with actual data, the errors incurred by applying empirical methods to compound channel flows have been quantified and found to depend on the particular method used.

Keywords: Discharge estimation, flow resistance, Equatorial River, overbank flow, velocity distribution.



Publication:

Chang, C.K., Ab. Ghani, A., Abdullah, R. & Zakaria, N.A. (2008). Sediment Transport Modeling for Kulim River - A Case Study. *Journal of Hydro-environment Research*. IAHR & KWRA, Vol. 2, No.1, pp. 47-59. ISSN: 1570-6443, DOI: 10.1016/j.jher.2008.04.002.

Abstract

Rapid urbanization has accelerated impact on the catchment hydrology and geomorphology. This rapid development which takes place in river catchment will result in higher sediment yield and affect river morphology and river channel stability; its also becomes the main cause for serious flooding in urban areas. Therefore, it is necessary to predict and evaluate the river channel stability due to existing and future development. This study proceeds at Kulim River in Kedah state, a natural stream in Kedah, Malaysia. The FLUVIAL-12 model, an erodible-boundary model which simulates inter-related changes in channel-bed profile, width variation and changes in bed topography was selected for this study. Engelund-Hansen formula and roughness coefficient $n = 0.030$ were found to be the best combination to represent the sediment transport activity in the study reach, where good agreements were obtained for both water level and bed profiles between the measured data and predicted results by FLUVIAL-12 model. The model simulation results for existing conditions, future conditions and long-term modelling show that the sediment size and channel geometry in Kulim River changed significantly. However, modelled results show that changes in cross sectional geometry will be limited and erosion along the reach will be slow down from 2006 to 2016, thus Kulim River was predicted to be stable at most locations.

Keywords: Alluvial river, Sediment transport, FLUVIAL-12 model, River channel stability, Long-term simulation.



Publication:

Azamathulla, H.Md., Ab. Ghani, A., Zakaria, N.A., Chang, C.K. & Leow, C.S. (2008). Knowledge Extraction from Trained Neural Network Scour Models. *Modern Applied Science*, Canadian Center of Science and Education, Vol.2, No.4, pp. 52-61, ISSN: 1913-1844.

Abstract

The study extends the earlier contribution of Azamathulla et al. in 2005, Artificial neural networks (ANNs), due to their excellent capabilities for modelling complex processes, have been successfully applied to a variety problems in hydraulics/ however, one of the major criticism of ANNs is that they are just black-box models, since a satisfactory explanation of their behaviour has not been offered. They, in particular, do not explain easily how the inputs are related to the output, and also whether the selected inputs have any significant relationship with an output. In this paper, a perturbation analysis for determining the order of influence of the elements in the vector on the output vector is discussed. The approached is illustrated though networks recommended in Azamathulla et. al. (2005) for prediction of scour using neural networks. The analyses of the results suggest that each variable in the input vector (discharge intensity, head, tail water depth, bed material, lip angle and radius of the bucket) influences the depth of scour in different ways. However, the magnitude of the influence cannot be clearly quantified by this approach. Further it adds that the selection of input vector based on linear measures between the variable of interest, which is commonly employed, may still include certain spurious elements that only increase the complexity of the model.

Keywords: Neural Networks, Scour, Spillways.



Publication:

Azamathulla, H.Md., Lai, S.H., Ab. Ghani, A., Zakaria, N.A., Chang, C.K., Leow, C.S. & Abu Hasan, Z. (2008). Genetic Programming to Predict Ski-Jump Bucket Spillway Scour. *Journal of Hydrodynamics*, Elsevier, Vol. 20, No. 4, pp. 477-484. ISSN: 1001-6058, DOI: 10.1016/S1001-6058(08)60083-9.

Abstract

Researchers in the past had noticed that application of Artificial Neural Networks (ANN) in place of conventional statistics on the basis of data mining techniques predicts more accurate results in hydraulic predictions. Mostly these works pertained to applications of ANN. Recently, another tool of soft computing, namely, Genetic Programming (GP) has caught the attention of researchers in civil engineering computing. This article examines the usefulness of the GP based approach to predict the relative scour depth downstream of a common type of ski-jump bucket spillway. Actual field measurements were used to develop the GP model. The GP based estimations were found to be equally and more accurate than the ANN based ones, especially, when the underlying cause-effect relationship became more uncertain to model.

Keywords: Genetic Programming (GP), neural networks, spillway scour, ski-jump bucket.

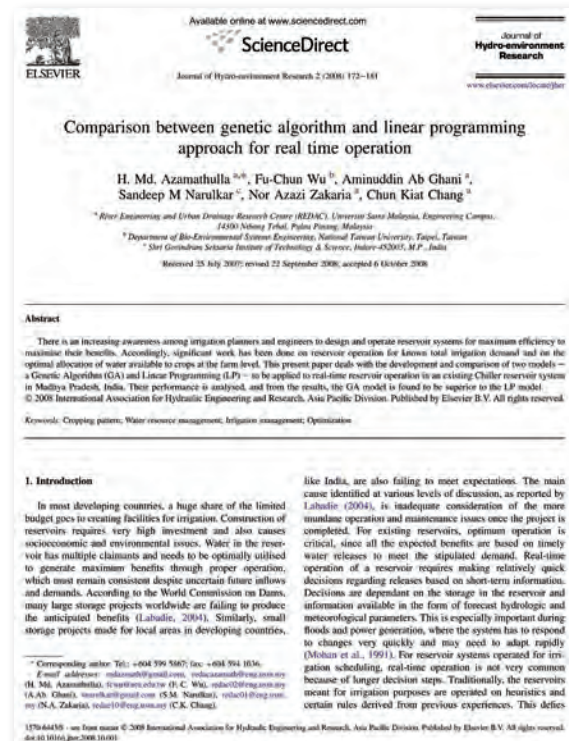
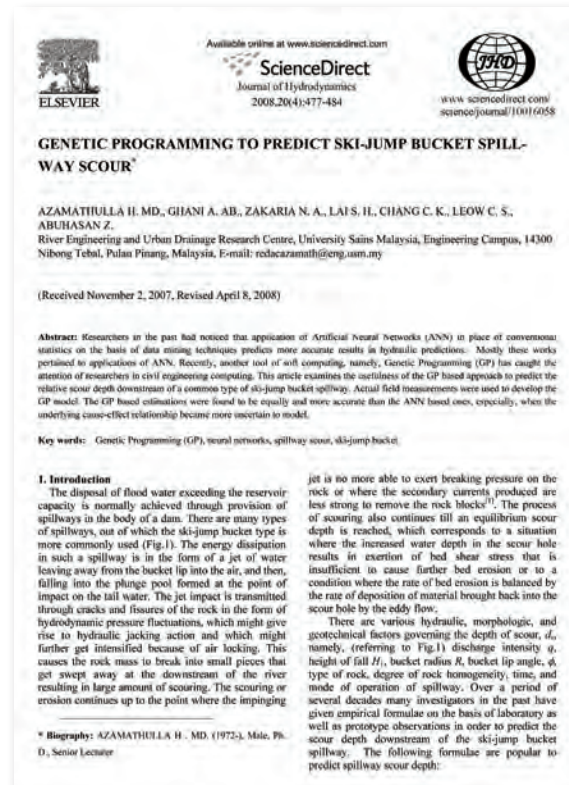
Publication:

Azamathulla, H.M., Ab. Ghani, A., Zakaria, N.A., Chang, C.K., Wu, F.C. & Narulkar, S.M. (2008). Comparison between Genetic Algorithm and Linear Programming approach for Real-Time Operation. *Journal of Hydro-environment Research*, IAHR & KWRA, Vol. 2, No.3, pp. 172-181. ISSN: 1570-6443, DOI: 10.1016/j.jher.2008.10.001

Abstract

There is an increasing awareness among irrigation planners and engineers to design and operate reservoir systems for maximum efficiency to maximise their benefits. Accordingly, significant work has been done on reservoir operation for known total irrigation demand and on the optimal allocation of water available to crops at the farm level. This present paper deals with the development and comparison of two models e a Genetic Algorithm (GA) and Linear Programming (LP) e to be applied to real-time reservoir operation in an existing Chiller reservoir system in Madhya Pradesh, India. Their performance is analysed, and from the results, the GA model is found to be superior to the LP model.

Keywords: Cropping pattern, Water resource management, Irrigation management, Optimization.



Publication:

Azamathulla, H.Md., Chang, C.K., Ab. Ghani, A., Zakaria, N.A., Ariffin, J. & Abu Hasan, Z. (2009). An ANFIS-based Approach for Predicting the Bed Load for Moderately Sized Rivers. *Journal of Hydro-environment Research*, IAHR & KWRA, Vol. 3, No.1, pp. 35-44, ISSN: 1570-6443, DOI: 10.1016/j.jher.2008.10.003

Abstract

A total of 346 sets of bed-load data obtained from the Kinta River, Pari River, Kerayong River and Langat River were analyzed using four common bed-load equations. These assessments, based on the median sediment size (d_{50}), show that the existing equations were unable to predict the measured bed load accurately. All existing equations over-predicted the measured values, and none of the existing bed-load equations gave satisfactory performance when tested on local river data. Therefore, the present study applies a new soft computing technique, i.e. an adaptive neuro-fuzzy inference system (ANFIS), to better predict measured bed-load data. Validation of the developed network (ANFIS) was performed using a new set of bed-load data collected at Kulim River. The results show that the recommended network can more accurately predict the measured bed-load data when compared to an equation based on a regression method.

Keywords: Sediment transport, Bed load, Loose-bed rivers, ANFIS, Malaysia.

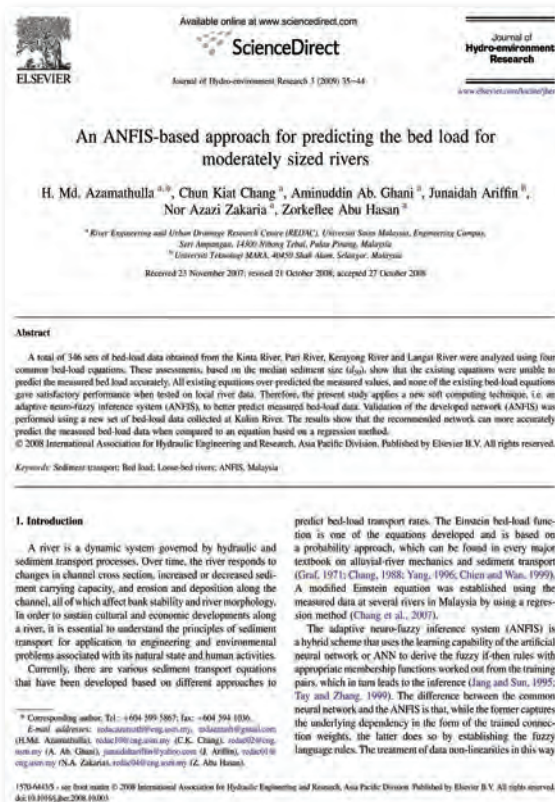
Publication:

Leow, C.S., Abdullah R., Zakaria, N.A., Ab. Ghani, A. & Chang, C.K. (2009). Modelling Urban River Catchment: A Case Study in Malaysia. *Proceedings of the Institution of Civil Engineers: Water Management*, Vol. 162, No. 1, pp. 25-34. ISSN: 1741-7589, DOI: 10.1680/wama.2009.162.1.25

Abstract

Generally, many rivers within urban catchments in Malaysia are being altered from their natural states to meet the demand of developments. Most of these rivers have also become the receiving water body for urban drainage systems. Therefore, it has become extremely difficult to separate river from the rest of the drainage system. Study of interaction between such river and urban drainage is necessary for urban drainage planning and design. Present study showcases how urban river modelling using InfoWorks Collection System (CS) on Berop River, Perak (Malaysia), can assist stormwater system design. Calibrated using historical flood event, the developed model was used for evaluation of various design storms, possible scenarios as well as existing and future landuse condition. The study found that within a data scarcity condition, InfoWorks CS played a significant role in providing good platform for stormwater system modelling as well as satisfactory simulations and analyses for complex combination of river and urban drainage stormwater system. This is the much needed advantage for practising engineers in time saving stormwater system design.

Keywords: Floods & Floodworks, mathematical modelling, sewers and drains.



Publication:

Azamathulla, H.Md., Ab. Ghani, A. & Zakaria, N.A. (2009). ANFIS Based Approach to Predicting Scour Location of Spillway. *Proceedings of the Institution of Civil Engineers: Water Management*, Vol.162, No. 6, pp. 399-407. ISSN: 1741-7589, DOI:10.1680/wama.2009.162.6.399.

Abstract

A spillway with a trajectory bucket as an energy dissipator satisfies the requirements of both safety and economy. Many researchers have developed empirical formulae to predict scour location considering different hydraulic parameters and bucket configurations. An attempt has been made in this paper to estimate the location of maximum scour using parameters such as q , H_1 , R , d_{50} , d_w and the lip angle of the bucket using an adaptive neuro fuzzy inference system (ANFIS). Extensive experimental results were collected and analysed in order to investigate the effect of different parameters on throw distance and scour location downstream of a trajectory bucket spillway. It was found that the scour parameter is a function of the fall Froude number, ratio of head to tailwater depth, ratio of radius of trajectory bucket to head, ratio of sediment mean size to head and lip angle of the bucket. The functional relationship is expressed in dimensionless form. This paper also presents an alternative to the regression in the form of neural fuzzy modelling. The results of this modelling were compared with the regression equation and it was found that the ANFIS results are highly satisfactory. The results of this study can be used to predict the location of maximum scour downstream of the trajectory bucket spillway.

Keywords: Hydraulics & hydrodynamics, models (physical), river engineering.

Publication:

Azamathulla, H.Md., Ab. Ghani, A., Zakaria, N.A. & Guven, A. (2010). Genetic Programming to Predict Bridge Pier Scour. *Journal of Hydraulic Engineering*, ASCE, Vol. 136, No. 3, pp. 165-169. ISSN: 0733-9429 DOI: 10.1061/JASCE_HY.1943-7900.0000133.

Abstract

Bridge-pier scour is a significant problem for the safety of bridges. Extensive laboratory and field studies have been conducted examining the effect of relevant variables. This note presents an alternative to the conventional regression-based equations (HEC-18 and regression equation developed by the writers), in the form of artificial neural networks (ANNs) and genetic programming (GP). There had been 398 data sets of field measurements that were collected from published literature and were used to train the network or evolve the program. The developed network and evolved programs were validated by using the observations that were not involved in the training. The performance of GP was found more effective when compared to regression equations and ANNs in predicting the scour depth at bridge piers.

Keywords: Bridge pier, Genetic programming, Artificial neural networks, Local scour, Radial basis function.



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A spillway with a trajectory bucket as an energy dissipator satisfies the requirements of both safety and economy. Many researchers have developed empirical formulae to predict scour location considering different hydraulic parameters and bucket configurations. An attempt has been made in this paper to estimate the location of maximum scour using parameters such as q , H_1 , R , d_{50} , d_w and the lip angle of the bucket using an adaptive neuro fuzzy inference system (ANFIS). Extensive experimental results were collected and analysed in order to investigate the effect of different parameters on throw distance and scour location downstream of a trajectory bucket spillway. It was found that the scour parameter is a function of the fall Froude number, ratio of head to tailwater depth, ratio of radius of trajectory bucket to head, ratio of sediment mean size to head and lip angle of the bucket. The functional relationship is expressed in dimensionless form. This paper also presents an alternative to the regression in the form of neural fuzzy modelling. The results of this modelling were compared with the regression equation and it was found that the ANFIS results are highly satisfactory. The results of this study can be used to predict the location of maximum scour downstream of the trajectory bucket spillway.

1. INTRODUCTION

The use of a trajectory bucket spillway with a plunge pool can be a safe and economical means of energy dissipation of flows. The trajectory bucket energy dissipator is able to throw the jet at a relatively safe distance from the bucket lip. It has some economic advantages over other energy dissipators. When geologic and topographic conditions permit, a trajectory bucket (also called flip bucket and ski jump bucket type of energy dissipator) is generally the most economical at sites with geological hard strata. The plunge pool develops as a result of self-accrual of the jet from jet energy at the point of impact. For sites in which there is not enough energy to initiate the high energy of the jet, the construction of a pre-constructed plunge pool is necessary as it dissipates energy by throwing the jet of water at a sufficient distance away from the spillway bucket. The scour is usually formed downstream of the point of impingement of the ski-jump jet. The reinitiation of this scour hole may cause danger to the stability of the structure by causing a structural failure or by increased seepage. The time of stability of the

downstream river bed and side slopes and the formation of a mound of eroded material thus raises the tailwater level and, after undesirable effects of such a dissipator.

It is important to ensure that the scour will not progress upstream to the extent that the safety of the structure might be in danger. High-velocity flow leaving the trajectory bucket will form a large amount of spray as it is dispersed into the air. The ski jump jet also spreads laterally in the downstream direction along the side banks. Therefore, suitable protection for the excavated banks is necessary. Transition slopes on both flanks of the plunge pool may be chosen, based on geologic conditions prevailing at the site. It is also necessary to prevent the rise of the dam from undermining owing to the flow cascading over the lip of the bucket. This can be done by providing a concrete apron downstream of the flip bucket. Buckets may be high or low, depending upon their location with respect to the riverbed. Scour locations are directly affected by tailwater level and current dimension, which alter the path of the jet entering the water. As a result, it is likely that scour location is shifted further downstream than the actual jet trajectory indicates.

Over a period of several decades many investigators have given empirical formulae based on laboratory as well as prototype observations in order to predict the scour location downstream of the flip bucket spillway. These formulae are very convenient to use but have a major drawback in that they involve identification, approximation and averaging of widely varying prototype conditions. As a result, the predicted scour locations may be considerably different from their actual values. Apart from the complexity of the phenomenon, this could also be attributable to the limitations of the analytical tools used by most of the earlier investigators, namely statistical regression.

The use of a soft computing tool such as artificial neural networks (ANN) in place of regression for the problem under consideration meets success, as shown by Azamathulla et al. (2009). This inspired the present work in which the scour problem is tackled with the help of another soft computing tool – adaptive neuro fuzzy inference system (ANFIS) – which is commonly known in its first stage. In the current study the ANFIS is employed to predict the location of maximum scour downstream of the trajectory bucket spillway involved. The scour depth location would be useful information for designing the plunge pool.

Water Management 162 (June 2009) ANFIS-based approach to predicting scour location of spillway Azamathulla et al. 399

TECHNICAL NOTES

Genetic Programming to Predict Bridge Pier Scour

H. Md. Azamathulla, M.ASCE¹; Aminuddin Ab Ghani²; Nor Azazi Zakaria³; and Aytaç Guven⁴

Abstract: Bridge-pier scour is a significant problem for the safety of bridges. Extensive laboratory and field studies have been conducted examining the effect of relevant variables. This note presents an alternative to the conventional regression-based equations (HEC-18 and regression equation developed by the writers), in the form of artificial neural networks (ANNs) and genetic programming (GP). There had been 398 data sets of field measurements that were collected from published literature and were used to train the network or evolve the program. The developed network and evolved program were validated by using the observations that were not involved in the training. The performance of GP was found more effective when compared to regression equations and ANNs in predicting the scour depth at bridge piers.

DOI: 10.1061/(ASCE)HY.1943-7900.0000133

CE Database subject headings: Bridges; Piers; Computer programming; Neural networks; Scour

Author keywords: Bridge pier; Genetic programming; Artificial neural network; Local scour; Radial basis function.

Introduction

The presence of a bridge pier in a channel may cause an abrupt change in the approach flow velocity, which may result in local scour at piers. The failure of Black Mountain bridge in New Zealand was a result of undermining of its piers in a riverbed (Mellish and Coleman 2000). The mechanism of flow around a pier structure is so complicated that it is difficult to establish a general empirical model to predict the scour depth d_s . A reliable estimation of d_s is of paramount importance in safe, economic, and technically sound bridge pier design. Most previous formulae for d_s available in the literature have been developed using conventional regression methods. Johnson (1995) reported that the Melville and Sutherland formula tends to overpredict d_s to greater extent than any other formula. Recently, Mohamed et al. (2005) showed that the Lauren and Toch (1950) and the Colorado State University (CSU) formulae (Mohamed et al. 2005) give reasonable estimates, while the Melville and Sutherland (1950) and Jain and Fischer (1980) formulae overpredict pier scour based on the

computation of some bridge pier scour formulae using field and laboratory data.

Alternative fitting approaches such as artificial neural networks (ANNs) (Liu et al. 2007) and adaptive nonlocality neural network system (Liu et al. 2007) have been recently shown to yield effective estimates of d_s . ANNs have been reported to provide reasonably good solutions for hydraulic engineering problems, in cases of highly nonlinear and complex relationships among the input-output pairs in corresponding data (Azamathulla et al. 2005, 2006).

The objective of this study is to predict d_s using genetic programming (GP). The performance of the proposed GP model is compared with a standard radial basis function (RBF) neural network and conventional regression-based equations. The explicit formulation of the GP model is also presented.

Local Scour Problem around a Pier

The equilibrium scour depth d_s around a circular pier in a steady flow over a bed of uniform, spherical, and noncohesive sediment depends on numerous groups of variables characterizing flow, sediment characteristics, and pier geometry. Extensive field data sets were obtained for the model developments in this study from Lamberti and Mueller (1999) (384 sets of data) and Mohamed et al. (2005) (14 sets of data). Table 1 summarizes the ranges of field data available such as pier width (b), length of pier (L), flow velocity (V), flow depth (y), mean diameter of bed material (d_m), and standard deviation bed grain size (σ).

Neural Network Model

ANNs provide a random mapping between an input and an output vector, typically consisting of three layers of neurons, namely, input, hidden, and output, with each neuron acting as an independent computational element. Neural networks derive their

Publication:

Julien, P.Y., Ab. Ghani, A., Zakaria, N.A., Abdullah, R. & Chang, C.K. (2010). Case Study: Flood Mitigation of the Muda River, Malaysia. *Journal of Hydraulic Engineering*, ASCE, Vol. 136, No. 4, pp. 251-261. ISSN: 0733-9429, DOI: 10.1061/(ASCE)HY.1943-7900.0000163.

Abstract

The 2003 flood of the Muda River reached 1,340 m³/s at Ladang Victoria and adversely impacted 45,000 people in Malaysia. A flood control remediation plan proposed a levee height based on 50-year discharge of 1,815 m³/s obtained from hydrologic models. This design discharge falls outside the 95% confidence intervals of the flood frequency analysis based on field measurements. Instream sand and gravel mining operations also caused excessive riverbed degradation, which largely off sets apparent benefits for flood control. Pumping stations have been systematically required at irrigation canal intakes. Several bridge piers have been severely undermined and emergency abutment protection works were needed in several places. Instream sand and gravel mining activities should be replaced with offshore mining in the future.

Keywords: Flood mitigation, Flood control, Hydrologic model, Hydraulic engineering, Gravel mining.

Publication:

Ab. Ghani, A., Ali, R., Zakaria, N.A., Abu Hasan, Z., Chang, C.K. & Ahamad, M.S.S. (2010). A Temporal Change Study of the Muda River System over 22 Years. *International Journal of River Basin Management*, IAHR, IAHS & INBO, Vol. 8, No. 1, pp. 25-37. ISSN: 1571-5124, DOI: 10.1080/15715121003715040.

Abstract

The Muda River has been dramatically affected by unsustainable human activities that scarified environmental values for national development. The removal of the forest canopy causes a decrease in the interception and transpiration in a basin. The decrease in transpiration leads to an increase in the amount of water stored in the soil. These changes can increase the soil's moisture content, allowing more water to be available to drain into channels. Tree clearing can also cause increased erosion at logged sites and a subsequent increase in sediment yield. In this study, an investigation of the spatial and temporal changes in the environment imposed by new land usages on a long timescale (over 22 years) was carried out in the Muda River area. Detecting the changes in land usage will help predict both consequent changes in the Muda River's behaviour and flood risks. In addition, computer modelling (InfoWorks RS) was used to help determine the long term behaviour of the Muda River and its flooding behaviour.

Keywords: Land use, flooding, hydrodynamic modelling, floodplain, flood map.

Case Study: Flood Mitigation of the Muda River, Malaysia

P. Y. Julien, M.ASCE¹; A. Ab. Ghani²; N. A. Zakaria³; R. Abdullah⁴; and C. K. Chang⁵

Abstract: The 2003 flood of the Muda River reached 1,340 m³/s at Ladang Victoria and adversely impacted 45,000 people in Malaysia. A flood control remediation plan proposed a levee height based on a 50-year discharge of 1,815 m³/s obtained from hydrologic models. This design discharge falls outside the 95% confidence intervals of the flood frequency analysis based on field measurements. Instream sand and gravel mining operations also caused excessive riverbed degradation, which largely off sets apparent benefits for flood control. Pumping stations have been systematically required at irrigation canal intakes. Several bridge piers have also been severely undermined and emergency abutment protection works were needed in several places. Instream sand and gravel mining activities should be replaced with offshore mining in the future.

DOI: 10.1061/(ASCE)HY.1943-7900(2010)163

CE Database subject headings: Floods; Hydrologic models; Hydraulic engineering; Gravel; Mining; Malaysia.

Author keywords: Flood mitigation; Flood control; Hydrologic models; Hydraulic engineering; Gravel mining.

Introduction

Southeast Asia has long experienced a monsoon climate with dry and wet seasons. With mean annual rainfall precipitation locally in excess of 5,000 mm, the very intense rainstorms in the steep mountains of Malaysia have caused frequent and devastating flash floods. In the valleys, floodwaters spread over very wide flood plains developed for agriculture, predominantly rice paddies and oil palm. For centuries, residents of Malaysia have built houses on stilts to cope with frequent floods, and longhouses were built along the main rivers. Over the years, a large number of inhabitants have encroached into the flood plains, new roads, many dwellings are built on the river banks (Fig. 1). More recent industrial developments and rapid suburbanization foster lifestyle changes. With cars and housing close to the ground, flood control is subject to drastic changes. Urbanization also exacerbates flooding problems due to the increased runoff from impervious areas. As a result, the sediment transporting capacity of rivers also increases,

thus causing major perturbations to river equilibrium (Ab. Ghani et al. 2007; Chang et al. 2005).

The Muda River in Malaysia experiences floods every year, and the floods of 1996, 1998, and 1999 were particularly high (Table 1). The Department of Irrigation and Drainage in Malaysia (Jabatan Pengirisan dan Saliran Malaysia, also known as JPS or JPD) enacted a Flood Control Remediation Plan with the assistance of consultants such as Janitex Consulting Sdn Bhd (JPC) (2000). On October 6, 2003, flooding reached catastrophic proportions with a peak discharge of 1,340 m³/s, as shown on the flood hydrograph in Fig. 2. Fig. 3 illustrates the aerial extent of this flood, which adversely impacted 45,000 people in the State of Kedah.

The objectives of this paper are to review important issues relative to flood control in Southeast Asia and to specifically use the Muda River Flood as an example highlighting key aspects of hydraulic engineering designs. The paper covers issues relative to comparisons of hydrologic and hydraulic models. There is also a specific focus on the impact of instream sand and gravel mining.



Fig. 1. Riverbank communities impacted by the Muda flood

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Research paper

A temporal change study of the Muda River system over 22 years

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ABSTRACT

The Muda River has been dramatically affected by unsustainable human activities that scarified environmental values for national development. The removal of the forest canopy causes a decrease in the interception and transpiration in a basin. The decrease in transpiration leads to an increase in the amount of water stored in the soil. These changes can increase the soil's moisture content, allowing more water to be available to drain into channels. Tree clearing can also cause increased erosion at logged sites and a subsequent increase in sediment yield. In this study, an investigation of the spatial and temporal changes in the environment imposed by new land usages on a long timescale (over 22 years) was carried out in the Muda River area. Detecting the changes in land usage will help predict both the consequent changes in the Muda River's behaviour and flood risks. In addition, computer modelling (InfoWorks RS) was used to help determine the long term behaviour of the Muda River and its flooding behaviour.

Keywords: Land use; flooding; hydrodynamic modelling; floodplain; flood map

1 Introduction

Natural forces alone do not cause floods in Malaysia today; rather, floods are a by-product of the interaction between natural events and human activities. Continuous changes in land usage and climate affect the geomorphology of river systems (e.g., Toy et al. 2002; Houben et al. 2006). Many anthropogenic land usage patterns (e.g., agriculture, industrialization, commercial, residential) are concentrated along rivers and in the vicinity of floodplains, and subsequent changes throughout Malaysia. These activities are continually subjected to the catastrophe of flooding. In the light of Malaysia's vision of being an industrial nation by

2020, more and more floodplain areas are expected to be developed, thereby exposing even more people and property in the risk of flooding. Flooding occurs when the river cannot cope with extra water coming from the river catchment area, which causes the level of the water in the river to rise and a flood to occur (Hyndman and Hyndman 2006). Significant destruction and losses of property, life and money are the results of catastrophic floods. These hazards continue to be a threat in Malaysia, especially since people choose to occupy floodplains, ignore the dangers of such hazard zones, mismanage flood lands, overdevelop land and deplete natural resources at rates that the natural system can neither cope with nor adapt to (Abdullah 1999).

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Publication:

Yazdi, J., Sarkardeh, H., Azamathulla, H.Md. & Ab. Ghani, A. (2010). 3D Simulation of Flow Around A Single Spur Dike with Free-surface Flow. *International Journal of River Basin Management*, IAHR, IAHS & INBO, Vol. 8, No. 1, pp. 55-62. ISSN: 1571-5124, DOI: 10.1080/15715121003715107.

Abstract

In the present study, flow patterns around a single spur dike (also term a groyne) with free-surface flow was simulated using a numerical model known as Fluent. The model solves the fully three-dimensional, Reynold-averaged Navier-Stokes equation to predict flow near the structure where three-dimensional flow is dominant. To treat the complex free-surface flow, the volume of fluid method with geometric reconstruction scheme was applied and turbulence was simulated using standard $k-\omega$ equations. In this research work, both a structured and unstructured mesh was used and the density of the mesh spacing was selected the highest near the walls and also free surface to obtain more accurate results. Comparison of free surface and velocities of 3D model showed good agreement with three experimental flume data obtained by other researchers. The reattachment length for various conditions was computed using the numerical results and flow pattern was presented for repelling, attracting and vertical spur dikes together. Also, bed-shear stress distribution was presented and the effects of flow discharge and the length and angle of the spur dike upon the bed shear-stress distribution were evaluated.

Keywords: Spur dike, simulation, numerical model, Fluent, $k-\omega$, free surface, VOF, shear stress.

Publication:

Azamathulla, H.Md. & Ab. Ghani, A. (2010). Genetic Programming to Predict River Pipeline Scour. *Journal of Pipeline Systems Engineering and Practice*, ASCE, Vol. 1, No. 3, pp. 127-132. ISSN: 1949-1190, DOI:10.1061/(ASCE)PS.1949-1204.0000060.

Abstract:

The process involved in the local scour below pipelines is so complex that makes it difficult to establish a general empirical model to provide an accurate estimation for scour. This technical note describes the use of genetic programming (GP) to estimate the pipeline scour depth. The data sets of laboratory measurements were collected from published literature and used to train the network or evolve the program. The developed network and evolved programs were validated by using the observations that were not involved in the training. The performance of GP was found to be more effective when compared with the results of regression equations and artificial neural networks modeling in predicting the scour depth around pipelines.

Keywords: Local scour, Genetic programming, Artificial neural networks, Radial basis function, Pipelines.



Publication:

Ab. Ghani, A., Azamathulla, H.Md., Chang, C.K., Zakaria, N.A. & Abu Hasan, Z. (2010). Prediction of Total Bed Material Load for Rivers in Malaysia: A Case Study of Langat, Muda and Kurau Rivers. *Journal of Environmental Fluid Mechanics*, Vol. 11, No. 3, pp. 307-318. ISSN: 1567-7419, DOI: 10.1007/s10652-010-9177-9.

Abstract

A soft computational technique is applied to predict sediment loads in three Malaysian rivers. The feed forward-back propagated (schemes) artificial neural network (ANNs) architecture is employed without any restriction to an extensive database compiled from measurements in Langat, Muda, Kurau different rivers. The ANN method demonstrated a superior performance compared to other traditional sediment-load methods. The coefficient of determination, 0.958 and the mean square error 0.0698 of the ANN method are higher than those of the traditional method. The performance of the ANN method demonstrates its predictive capability and the possibility of generalization of the modeling to nonlinear problems for river engineering applications.

Keywords: Alluvial channels, Artificial neural network, Total-sediment load, River engineering, Sediment transport.

Publication:

Mah, D.Y.S., Lai, S.H. & Zakaria, N.A. (2010). Modelling of Riparian-Imitated Constructed Wetland for Fish Habitat. *Journal of Natural Resources Research*, International Association for Mathematical Geology, Vol.19, No.3, pp.231-236. ISSN: 1520-7439, DOI: 10.1007/s11053-010-9122-0

Abstract

This paper presents a hydrodynamic-based investigation of constructed wetland suitability for fish habitat. A constructed wetland adjacent to river is manoeuvred to imitate riparian fish habitat by means of computer modelling. Flow-velocity conditions, water depths and effects of macrophytes to resistance of flow in constructed wetland are modelled and steered towards creating a favourable ground for natural substrate spawning of native fish species. The model suggests combination of two zones, which are a macrophyte zone for typical functions of a wetland and an open water zone with gravel bed to support fish reproductive cycles.

Keywords: Constructed wetland, drainage, fish spawning, hydraulic, riparian, urban.

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ORIGINAL ARTICLE

Prediction of total bed material load for rivers in Malaysia: A case study of Langat, Muda and Kurau Rivers

Aminuddin Ab. Ghani · H. Md. Azamathulla ·
Chun Kiat Chang · Nor Azazi Zakaria ·
Zorkellee Abu Hasan

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Abstract A soft computational technique is applied to predict sediment loads in three Malaysian rivers. The feed forward-back propagated (schemes) artificial neural network (ANNs) architecture is employed without any restriction to an extensive database compiled from measurements in Langat, Muda, Kurau different rivers. The ANN method demonstrated a superior performance compared to other traditional sediment-load methods. The coefficient of determination, 0.958 and the mean square error 0.0698 of the ANN method are higher than those of the traditional method. The performance of the ANN method demonstrates its predictive capability and the possibility of generalization of the modeling to nonlinear problems for river engineering applications.

Keywords Alluvial channels · Artificial neural network · Total-sediment load · River engineering · Sediment transport

1 Introduction

Sand and gravel have long been used as aggregate for construction of roads and building. Today, the demand for these materials continues to rise. In Malaysia, the main source of sand

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Modelling of Riparian-Imitated Constructed Wetland for Fish Habitat

Darrien Yau Seng Mah,^{1,2} Sai Hin Lai,¹ and Nor Azazi Zakaria¹

Received: 15 March 2010; accepted: 25 May 2010

This paper presents a hydrodynamic-based investigation of constructed wetland suitability for fish habitat. A constructed wetland adjacent to river is manoeuvred to imitate riparian fish habitat by means of computer modelling. Flow-velocity conditions, water depths and effects of macrophytes to resistance of flow in constructed wetland are modelled and steered towards creating a favourable ground for natural substrate spawning of native fish species. The model suggests combination of two zones, which are a macrophyte zone for typical functions of a wetland and an open water zone with gravel bed to support fish reproductive cycles.

KEY WORDS Constructed wetland, drainage, fish spawning, hydraulic, riparian, urban.

BACKGROUND

There is a tendency over the Southeast Asia region to line up rivers with concrete embankments causing a loss of natural riparian wetlands, particularly in an urban setting (see an example in Fig. 1). Lands are reclaimed to develop aesthetic water front as tourist attraction spots or for human settlement purposes. The tranquility of water element always promises high priced housing to fare striking amount of income for real estate developers. Little known to most people, upstream and downstream river systems may support different ecosystem due to its varied river morphology (Puseh and Hoffmann, 2000). Therefore, ecosystem conservation in urbanized river reaches is equally important. As once lost, it would take a great price to restore the river ecosystem.

Malaysian government is pushing for sustainable urban drainage system, where an element of

ecological drainage management is gaining emphasis. Constructed wetlands, basins and ponds are one of the general methods of surface runoff control, other than swales, filter strips, filter drains, permeable surfaces and infiltration devices (Scholes, Revitt, and Ellis, 2008). Runoff from settlements is channelled to these artificial structures before being discharged to waterways. Constructed wetlands exhibit various processes that occur in natural wetlands and integrated systems in which water, plants, animals, microorganisms, soil and air operate to improve surface runoff water quality (Shutes, 2001; Kohler and others, 2004).

MOTIVATIONS

The engineering design of constructed wetland is primarily as flood control (Koskiah, 2003), surface runoff storage (DID, 2000; CIRIA, 2001) and pollutant removal (Sindilariu, Welter, and Reiter, 2008). We argue here fish habitat can be incorporated systematically. Concrete-lined rivers have faster and stronger currents than natural rivers as a result of compounded and narrowed channel width. On the other hand, constructed wetlands adjacent to

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Publication:

Zakaria, N.A., Azamathulla, H.Md., Chang, C.K. & Ab. Ghani, A. (2010). Gene Expression Programming for Total Bed Material Load Estimation - A Case Study. *Science of the Total Environment*, Elsevier, Vol. 408, No.21, pp. 5078-5085. ISSN: 0048-9697, DOI: 10.1016/j.scitotenv.2010.07.048

Abstract

This paper presents Gene-Expression Programming (GEP), which is an extension to the genetic programming (GP) approach to predict the total bed material load for three Malaysian rivers. The GEP is employed without any restriction to an extensive database compiled from measurements in the Muda, Langat, and Kurau rivers. The GEP approach demonstrated a superior performance compared to other traditional sediment load methods. The coefficient of determination, R^2 ($=0.97$) and the mean square error, MSE ($=0.057$) of the GEP method are higher than those of the traditional method. The performance of the GEP method demonstrates its predictive capability and the possibility of the generalization of the model to nonlinear problems for river engineering applications.

Keywords: Alluvial channels, Sediment transport, Total bed material load, Gene Expression Programming, River engineering.

Publication:

Ayub, K.R., Zakaria, N.A., Abdullah, R. & Ramli, R. (2010). Water Balance: Case Study of A Constructed Wetland As Part of the Bio-Ecological Drainage System (BIOECODS). *Water Science & Technology*, pp. 1931-1936. ISSN: 0273-1223, DOI: 10.2166/wst.2010.473.

Abstract

The Bio-ecological Drainage System, or BIOECODS, is an urban drainage system located at the Engineering Campus, Universiti Sains Malaysia. It consists of a constructed wetland as a part of the urban drainage system to carry storm water in a closed system. In this closed system, the constructed wetland was designed particularly for further treatment of storm water. For the purpose of studying the water balance of the constructed wetland, data collection was carried out for two years (2007 and 2009). The results show that the constructed wetland has a consistent volume of water storage compared to the outflow for both years with correlation coefficients (R^2) of 0.99 in 2007 and 0.86 in 2009.

Keywords: BIOECODS, constructed wetland, evaporation, water balance, water resources.



Publication:

Musa, S., Zakaria, N.A., Lai, S.H. & Tjahjanto, D. (2010). The Drainage Exchange of Stormwater Potential in Flat Area Problems. *Journal of Environmental Science and Engineering*, Vol. 4, No. 10, pp. 1-8, ISSN: 1934-8932.

Abstract

Groundwater as an alternative source still does not contribute to the water supply in area of Parit Raja because of the limitation of water availability in the ground. This lacking of groundwater could be caused by the circumstance that the top layer of soil is dominated by compacted clay around 2 meters in which its permeability is small, so the water is difficult to infiltrate the ground. The recharge well technique was designed based on the flat area problems, layer of real condition, flow water table and low infiltration rate. Resistivity soundings were made at existing wells to assess the subsurface layers. Besides that, the past records on floods event, sub surface and surface studies were collected around study area as preliminary studies. It was presented that the study area promised good prospects to increase the capability of groundwater and contribute to the drainage system by reducing the volume of rainfall runoff using the recharge well technique.

Keywords: Groundwater, recharge well, water supply, drainage system.

Publication:

Azamathulla, H.Md., Ab. Ghani, A., Chang, C.K., Abu Hasan, Z. & Zakaria, N.A. (2010). Machine Learning Approach to Predict Sediment Load - A Case Study. *CLEAN – Soil, Air, Water*, Vol. 38, No. 10, pp. 969–976. ISSN: 1863-0650, DOI: 10.1002/clean.201000068.

Abstract

In this study, a novel machine learning technique called the support vector machine (SVM) method is proposed as a new predictive model to predict sediment loads in three Malaysian rivers. The SVM is employed without any restriction to an extensive database compiled from measurements in the Muda, Langat, and Kurau rivers. The SVM technique demonstrated a superior performance compared to other traditional sediment-load methods. The coefficient of determination, 0.958, and the mean square error, 0.0698, of the SVM method are higher than those of the traditional method. The performance of the SVM method demonstrates its predictive capability and the possibility of the generalization of the model to nonlinear problems for river engineering applications.

Keywords: Alluvial channels, River engineering, Sediment transport, Support vector machine, Total sediment load.

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The Drainage Exchange of Stormwater Potential in Flat Area Problems

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Abstract: Groundwater as an alternative source still does not contribute to the water supply in area of Parit Raja because of the limitation of water availability in the ground. This lacking of groundwater could be caused by the circumstance that the top layer of soil is dominated by compacted clay around 2 meters in which its permeability is small, so the water is difficult to infiltrate the ground. The recharge well technique was designed based on the flat area problems, layer of real condition, flow water table and low infiltration rate. Resistivity soundings were made at existing wells to assess the subsurface layers. Besides that, the past records on floods event, sub surface and surface studies were collected around study area as a preliminary studies. It was presented that the study area promised good prospects to increase the capability of groundwater and contribute to the drainage system by reducing the volume of rainfall runoff using the recharge well technique.

Key words: Groundwater, recharge well, water supply, drainage system.

1. Introduction

As we know that south Malaysia of Peninsular has been nature filled by peat soil and deep of clay layers. Low flows are often important ecologically. Some time, low flow movement to the rivers uncontrolled when the wet season out come. Then, flooding always occurred during rainy season caused by flat area and lacking of proper drainage system.

Recently, the development of Districts of Batu Pahat

has caused the increasing number of inhabitant. More even in area of Parit Raja, the growing of population more than other areas since UTHM (Universiti Tun Hussein Onn Malaysia) is developed, which has been established as a big university. With the increase of buildings and pavement, the green area smaller causes too much stress on the remaining drainage area, which can cause several flooding in rural or urban especially Parit Raja area [1]. Besides, the drainage system in UTHM also had faced some terrible condition where in the end of year 2006, the flood happened and it caused partially sunk of UTHM old campus. This condition happened because of the poor drainage system around the campus. Thus, this research is then carried out to find out the best way to overcome that poor drainage system where the drilled well that is used to generate the source of water can be a part of drainage system during wet seasons to mitigate the flood.

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Clean – Soil, Air, Water 38(10), 969–976

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Research Article

Machine Learning Approach to Predict Sediment Load – A Case Study

In this study, a novel machine learning technique called the support vector machine (SVM) method is proposed as a new predictive model to predict sediment loads in three Malaysian rivers. The SVM is employed without any restriction to an extensive database compiled from measurements in the Muda, Langat, and Kurau rivers. The SVM technique demonstrated a superior performance compared to other traditional sediment-load methods. The coefficient of determination, 0.958, and the mean square error, 0.0698, of the SVM method are higher than those of the traditional method. The performance of the SVM method demonstrates its predictive capability and the possibility of the generalization of the model to nonlinear problems for river engineering applications.

Keywords: Alluvial channels; River engineering; Sediment transport; Support vector machine; Total sediment load

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1 Introduction

The prediction of river sediment load constitutes an important issue in river engineering. The sediment can increase the elevation of channel beds with excess sand and gravel for tens to hundreds of kilometers downstream. Such aggradation promotes the lateral migration of channels and may cause serious flooding during rainstorms due to the loss of channel capacity necessary to convey floodwaters [1]. Currently, there are various sediment transport equations that have been developed based on different approaches to predict the total load transport rates. Conventional approaches used in model modeling efforts begin with an assumed form of an empirical or analytical equation and follow with a regression analysis or curve fitting using experimental data to determine the unknown model coefficients [2]. Although this paper provides new understanding, the determination of sediment transport loads remains a challenging task.

In recent years, rapid development in Malaysia has led to an increased demand for river sand as a source of construction material, which has resulted in a diminishing of river sand mining activities that have given rise to various problems that require urgent action by the authorities. These include riverbank erosion, riverbed degradation, river bedrock exposure, and deterioration of river water quality. Very often, over-mining occurs, which jeopardizes the health of the river and the environment in general. The present study summarizes the results based on field data collected at three river catchments in Malaysia, i.e., the river

Muda, the river Langat, and the river Kurau. Fieldwork on selected sites for the three rivers was performed to assess the capacity of the river to convey both water and sediment. Data collection on the bed material was used to characterize the physical characteristics of the sediment responsible for sediment transport, which determines the river response in terms of erosion and deposition. The three rivers clearly have bed material sizes in the sand-gravel range based on the collected data in the present study [3]. This study shows that the measured load can be predicted accurately for Malaysian rivers using the support vector machine (SVM) technique.

Although a number of successful attempts have been recorded by Azamathulla et al. [4], a wider application of theoretical models is restrained by their heavy demand in terms of computing capacity and time. Alternatively, soft computing techniques, such as artificial neural networks (ANNs), evolutionary computation (EC), fuzzy logic (FL), and SVMs, have been successfully applied in river engineering problems for the past two decades [5, 6].

Only a few studies on the application of SVM in water engineering are available in the literature. Bhattacharya et al. [7] used machine learning to model sediment transport. Sivaprasadarao and Muthu [8] suggested the use of SVM in the extrapolation of rating curves. Yu et al. [9] established a real-time extrapolation model. Khan and Goudali [10] examined the potential of the SVM in the long-term prediction of lake water levels and obtained quite good results. Most recently, Sotomayor and Ojeda [11] issued a special study on data driven modeling and evolutionary optimization for river basin management. They presented a brief overview of the most popular techniques and some of the experience of the authors in data driven modeling relevant to river basin management.

2 Study Area and Data Used

The present study covers three rivers, i.e., the river Muda, the river Langat, and the river Kurau, which have different levels of sand

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Abbreviations: DR, discrepancy ratio; MSE, mean square error; SVM, support vector machine; SVR, support vector regression.

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Publication:

Roshan, R., Azamathulla, H.Md., Marosi, M., Sarkardeh, H., Pahlavan, H. & Ab. Ghani, A. (2010). Hydraulics of Stepped Spillways With Different Numbers of Steps. *Dams and Reservoirs*, Vol. 20, No. 3, pp. 131–136. ISSN: 1368-1494, DOI: 10.1680/dare.2010.20.3.131

Abstract

This paper describes the study of two physical models that were built to investigate the energy dissipation and flow regimes for different discharges over stepped spillways with different numbers of steps. These physical models had a general slope of 19.2% and had 12 and 23 steps respectively. Experiments were carried out for a wide range of discharges. The hydraulic parameters of the flow over the models were measured and the energy dissipation of flow was also calculated. Results showed that the 12-step model dissipated more energy than the 23-step model. However, the flow regimes that occurred in the 23-step model were considered more acceptable than in the 12-step model. The experiments showed that energy dissipation at lower flow rates were similar in both cases. However, in the skimming flow regime at higher discharges, energy dissipation was about 12% less in the 23-step model than in the 12-step model.

Keywords: Flow regimes, Hydraulic parameters, Physical model, Skimming flows, Stepped spillways.

Publication:

Azamathulla, H.Md. & Ab. Ghani, A. (2011). Genetic Programming for Predicting Longitudinal Dispersion Coefficients in Streams. *Journal of Water Resource Management*, Vol. 25, No. 6, pp. 1537-1544. ISSN: 0920-4741, DOI: 10.1007/s11269-010-9759-9

Abstract

This paper presents a genetic programming (GP) approach to predict the longitudinal dispersion coefficients in natural streams. Published data were compiled from the literature for the dispersion coefficient for a wide range of flow conditions, and they were used for the development and testing of the proposed method. The proposed GP approach produced excellent results ($R^2 = 0.98$ and $RMSE = 0.085$) compared to the existing predictors (Rajeev and Dutta, *Hydrol Res* 40(6):544–552, 2009, $R^2 = 0.345$ and $RMSE = 1778.6$) for dispersion coefficient.

Keywords: Streams, Rivers, Dispersion, Pollutants, GP.



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Genetic Programming for Predicting Longitudinal Dispersion Coefficients in Streams

Hazi Mohammad Azamathulla ·
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Abstract This paper presents a genetic programming (GP) approach to predict the longitudinal dispersion coefficients in natural streams. Published data were compiled from the literature for the dispersion coefficient for a wide range of flow conditions, and they were used for the development and testing of the proposed method. The proposed GP approach produced excellent results ($R^2 = 0.98$ and $RMSE = 0.085$) compared to the existing predictors (Rajeev and Dutta, *Hydrol Res* 40(6):544–552, 2009, $R^2 = 0.345$ and $RMSE = 1778.6$) for dispersion coefficient.

Keywords Streams · Rivers · Dispersion · Pollutants · GP

Notations

B, W Width (m),
H Depth (m),
U Velocity (m/s),
 U_s Shear velocity (m/s),
 K_L Longitudinal dispersion coefficient (m^2/s)

1 Introduction

The longitudinal dispersion of pollutants in rivers is crucial to hydraulic and environmental engineers for designing outfalls or water intakes and evaluating risks from accidental releases of hazardous contaminants (Deng et al. 2001). Many researchers have focused on the mechanisms of longitudinal dispersion in rivers, beginning with

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Azamathulla, H.Md. & Ab. Ghani, A. (2011). An ANFIS-Based Approach for Predicting the Scour Depth at Culvert Outlets. *Journal of Pipeline Systems Engineering and Practice*, Vol. 2, No. 1, pp. 35-40, ISSN: 1949-1190, DOI: 10.1061/(ASCE)PS.1949-1204.0000066

Abstract

The processes involved in the local scour at culverts are so complex and that makes it difficult to establish a general empirical model to provide accurate estimation for scour. This paper describes the use of adaptive neurofuzzy inference system (ANFIS) to estimate the scour depth at culvert outlets. The data sets of laboratory measurements were compiled from published literature and used to train the ANFIS network. The developed network was validated by using the observations that were not involved in training. The performance of ANFIS was found to be more effective ($R^2=0.94$) when compared with the results of regression equations and artificial neural networks modelling in predicting the scour depth at culvert outlets ($R^2=0.78$). Further work is required to collect field data of scour at culvert outlets to train the genetic programming approach and validate its usefulness.

Keywords: Radial basis function, Culverts, Neurofuzzy, Artificial neural networks, ANN, Local scour.

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Abstract

This paper discusses the flow pattern and hydraulic performance of a Gross Pollutant Trap (GPT), designed and patented by River Engineering and Drainage Research Centre (REDAC) at Universiti Sains Malaysia. Stormwater problems have become more severe due to the increase in urbanization. The increase in the amount of impervious surface in urban areas produces more stormwater runoff that is carried to the receiving bodies of water. The higher runoff volume also carries more pollutants (gross pollutants, sediments, and nutrients) from the contributing catchment area. Coarse sediments transported by stormwater runoff have negative effects on the receiving body of water and the aquatic environment by covering up aquatic habitats and clogging waterways. One of the challenges in designing a GPT for urban stormwater drainage is providing effective trapping without hindering the hydraulic function of the channel, thus, avoiding overspill or flooding. The current study presents a GPT design to meet these specific requirements of trapping efficiency and hydraulic function. The current GPT overcame the common problem of overspilling of gross pollutants in GPT by the introduction of additional overspill compartments that can handle excessive runoff and improve pollutant trapping in higher flow conditions. In laboratory testing, the prototype GPT was capable of achieving good trapping efficiency (over 80% for gross pollutants and over 60% for coarse sediments) without causing any overspill

Keywords: Gross Pollutant Trap, Sediment, Best management practice, Flow measurement.

ANFIS-Based Approach for Predicting the Scour Depth at Culvert Outlets

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Abstract: The processes involved in the local scour at culverts are so complex and that makes it difficult to establish a general empirical model to provide accurate estimation for scour. This paper describes the use of adaptive neurofuzzy inference system (ANFIS) to estimate the scour depth at culvert outlets. The data sets of laboratory measurements were compiled from published literature and used to train the ANFIS network. The developed network was validated by using the observations that were not involved in training. The performance of ANFIS was found to be more effective ($R^2=0.94$) when compared with the results of regression equations and artificial neural networks modelling in predicting the scour depth at culvert outlets ($R^2=0.78$). Further work is required to collect field data of scour at culvert outlets to train the genetic programming approach and validate its usefulness.

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CE Database subject headings: Culverts; Neural networks; Scour; Predictions.

Author keywords: Radial basis function; Culverts; Neurofuzzy; Artificial neural networks; ANN; Local scour.

Introduction

An essential feature in the hydraulic design of drainage-crossing hydraulic structures such as culverts or storm drains is determining the design capacity of flow capacity (Lim 1995). Accurate prediction of the dimensions of scour downstream from hydraulic structures is required to ensure foundations are properly designed and prevent damage to the structure as a result of undermining (Lirio and Day 2001). The estimation of scour characteristics at culvert outlets (Fig. 1) continues to be a concern for hydraulic engineers.

A number of empirical formulas have been developed in the past to estimate equilibrium scour depth at culvert outlets, including Opte (1967), Rajaratnam and Berry (1977), Rajaratnam (1981), Ruff et al. (1982), Rajaratnam and MacDougall (1983), Blaisdell and Anderson (1988), Abida and Townsend (1991), Lim (1995), and Chiew and Lim (1996). These traditional scour prediction equations (Table 1), although offering the engineer some guidance on the likely magnitude of maximum scour depth, are applicable only to a limited range of field conditions. A model for the prediction of scour downstream from culverts that is generally applicable to all circumstances is not currently available. However, the main deficiency of these formulas is that the empirical equations do not model actual scour processes. Most commonly,

regression relations are used to predict culvert outlet scour; however, regression analysis can have large uncertainties, which include major drawbacks pertaining to idealization of complex scour process, approximation and averaging widely varying prototype conditions. Thus, the estimated scour depths using regression equations can have large uncertainties, which can contribute to costly culvert failures.

Predictive approaches such as artificial neural networks (ANN) (Azamathulla et al. 2005) and adaptive neurofuzzy inference systems (ANFIS) (Azamathulla et al. 2008) have been recently shown to yield effective estimates of scour around hydraulic structures. ANNs have been reported to provide reasonably good solutions for hydraulic-engineering problems, particularly for cases of highly nonlinear and complex relationship among the input-output pairs in corresponding data (Gaven and Gural 2008; Azamathulla et al. 2010; Azamathulla and Ghani 2010).

The objective of this study is to develop an improved predictive model for estimating scour depth using ANFIS. The performance of the proposed ANFIS model is compared with a standard radial basis function (RBF) neural network and conventional regression-based equations (Lim 1995; Chiew and Lim 1996; Abt et al. 1984).

Analysis of Local Scour at Culvert Outlets

The variables influencing the equilibrium scour depth (d_s) at culvert outlets are listed as below (Lirio and Day 2001)

$$d_s = f(p, \rho, \mu, \gamma, d_o, D, W, W_o, \sigma, \rho_s, \rho_w, \sigma_w, K) \quad (1)$$

where d_s =maximum depth of scour; p =density of water; μ =dynamic viscosity of water; ρ_w =mean velocity at the outlet; d_o =pipe diameter for circular outlets and the outlet height for non-circular outlets; H =depth of water in the downstream receiving channel (tailwater depth); W =width of the receiving channel; W_o =width of the outlet; γ =acceleration due to gravity; ρ_s =density of the sediment bed material; d_m =median sediment

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Flow pattern and hydraulic performance of the REDAC Gross Pollutant Trap

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ABSTRACT

This paper discusses the flow pattern and hydraulic performance of a Gross Pollutant Trap (GPT) designed and patented by River Engineering and Drainage Research Centre (REDAC) at Universiti Sains Malaysia. Stormwater problems have become more severe due to the increase in urbanization. The increase in the amount of impervious surface in urban areas produces more stormwater runoff that is carried to the receiving bodies of water. The higher runoff volume also carries more pollutants (gross pollutants, sediments, and nutrients) from the contributing catchment area. Coarse sediments transported by stormwater runoff have negative effects on the receiving body of water and the aquatic environment by covering up aquatic habitats and clogging waterways. One of the challenges in designing a GPT for urban stormwater drainage is providing effective trapping without hindering the hydraulic function of the channel, thus, avoiding overspill or flooding. The current study presents a GPT design to meet these specific requirements of trapping efficiency and hydraulic function. The current GPT overcame the common problem of overspilling of gross pollutants in GPT by the introduction of additional overspill compartments that can handle excessive runoff and improve pollutant trapping in higher flow conditions. In laboratory testing, the prototype GPT was capable of achieving good trapping efficiency (over 80% for gross pollutants and over 60% for coarse sediments) without causing any overspill.

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1. Introduction

Gross pollutants are defined as discarded materials larger than 5 mm and include litter and debris, and coarse sediments are particles with grain sizes greater than 0.5 mm [1]. Litter in the stormwater system includes human-derived rubbish, such as paper, plastic, polystyrene, metal, and glass, that has been dumped, mainly illegally, into waterways or drains. Debris consists of organic materials including leaves, branches, twigs and grass clippings. Generally, coarse sediments are eroded soil particles originating from diffused sources, such as construction sites, land clearing sites and agricultural areas. All of the pollutants can potentially harm wildlife, especially those found in aquatic habitats, and can decrease the aesthetic qualities of the stormwater system and attract vermin. Fig. 1 shows the various types of gross pollutants trapped in receiving bodies. Based on the photographs, the gross pollutants were classified into several types of bottles,

plastic bags, polystyrene, paper, cans, twigs, leaves, boxes and old clothes. A study conducted in Melbourne, Australia, noted that urban areas contribute about 20–40 kg (dry mass) of gross pollutants per hectare per year to stormwater, equivalent to approximately 60,000 tons or 230,000 cubic meters of gross pollutants and about two billion tonnes of sediment [1].

The increase in urban population density and built-up areas directly or indirectly affects hydrological processes through changes in stormwater runoff or the stream flow regime: alterations in peak flow characteristics, decrease in water quality, and changes in a river's amenities. A shift in land use from agriculture to urban development generally removes vegetated land cover and contributes to increased surface imperviousness. This increased imperviousness will lead to more erosion of land surfaces. Eventually, the eroded sediment will be transported and then deposited in a waterway. Industrialization and urbanization are the main human activities that affect the environment by increasing the magnitude of pollution. Thus, increasing the amount of sediment deposited in conventional drainage systems in Malaysia [2]. Most of the sediment deposited in conventional drainage systems is caused by human activities, such as construction and road work; some deposition is also due to erosion from the surrounding areas. Gross pollutants and sediment deposits decrease the ability of urban drainage systems to convey stormwater runoff. As a result, urbanization increases flood runoff and can produce hazardous flash

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Abstract

Freshwater habitats are one of the planet's most important, yet most manipulated, environments. This is what happens in Sarawak that the environment has been radically changed due to urban developments. This paper is promoting the idea that we do not need a complicated but a simple tool like fuzzy inference system to strike a balance between the existence of peat swamp and the humans who live nearer and nearer to it. Conditions vital to the survival and continuity of a natural wetland system can be adapted as fuzzy rules. These rules are capable of providing indicators of how much wetland can be exploited and at the same time still allow the system to properly functioning as a wetland.

Keywords: Disappearing wetlands, Ecological, social interaction, Habitat, Indicator, Natural landscape, Nature conservation.

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Abstract

This paper presents the support vector machine approach to predict the longitudinal dispersion coefficients in natural rivers. Collected published data from the literature for the dispersion coefficient for wide range of flow conditions are used for the development and testing of the proposed method. The proposed SVM approach produce satisfactory results with coefficient of determination = 0.9025 and root mean square error = 0.0078 compared to existing predictors for dispersion coefficient.

Keywords: Support vector machine, Rivers, Dispersion Streams.

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RAPID COMMUNICATION

Conservation of Sarawak peat swamp in an urban landscape by fuzzy inference system

Darrien Yau Seng Mah

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Abstract Freshwater habitats are one of the planet's most important, yet most manipulated, environments. This is what happens in Sarawak that the environment has been radically changed due to urban developments. This paper is promoting the idea that we do not need a complicated but a simple tool like fuzzy inference system to strike a balance between the existence of peat swamp and the humans who live nearer and nearer to it. Conditions vital to the survival and continuity of a natural wetland system can be adapted as fuzzy rules. These rules are capable of providing indicators of how much wetland can be exploited and at the same time still allow the system to properly functioning as a wetland.

Keywords Disappearing wetlands · Ecological-social interaction · Habitat · Indicator · Natural landscape · Nature conservation

Background

Large parts of the capital Kuching city of Sarawak State, Malaysia, are erected on previously peatland that was transformed for cityscapes. Today, only a fraction of freshwater peat swamp remains at the outskirts of Kuching city in Matang area (see Fig. 1), but more and more houses are built alongside the linking road. Thus, the remnant of peat swamp should be adequately protected and properly

managed. In order to alleviate the rush to convert wetlands to other uses, it should seek to build wetland conservation into future land development plans (Duarte et al. 2008). The idea is to have natural infrastructure approach that emphasizes on providing space for plants and wildlife; at the same time, accommodating human uses, like the one depicted in the inset of Fig. 1.

Tropical wetlands are among the most biologically diverse and productive ecosystems on earth. Plants and animals associated with wetland habitats are integral to many food chain and life support systems. Wetlands also provide valuable services and functions to human population (TNDP 2006). Natural infrastructure in its simplest form comprises of hubs and corridors. A hub or patch is typically large, unfragmented areas that are critical for conserving important ecosystems. Corridors are linear features that serve to connect hubs of plant and animal populations, thus assuring the long-term viability of these populations and the larger ecosystem. Matrix is often developed lands such as cropland or urban areas. This approach creates a framework for environmental decisions that leverage the interactions of man and ecology.

Motivations

The approach often results in identifying a natural infrastructure network of interconnected green spaces (Benedict and McMahon 2001). It emphasizes on ecosystem values and functions to support long-term sustainability (Gill et al. 2007; USEPA 2010). Yet, how wide does the conservation buffer need to be? Unfortunately, there is no ideal buffer width. Management is deemed successful only if it preserves or increases the capacity of an ecosystem to produce the desired services in perpetuity. Current management of

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Support vector machine approach for longitudinal dispersion coefficients in natural streams

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1. Introduction

The longitudinal dispersion of pollutants in rivers is significant to practicing hydraulic and environmental engineers for designing outfalls or water intakes and for evaluating risks from accidental releases of hazardous contaminants [1]. Many researchers have contributed to the understanding of the mechanisms of longitudinal dispersion in rivers, beginning with the simplest dispersion of dissolved constituents in pipe flow [2]. Later, the concept of dispersion was extended to the mixing in open channels and further to natural streams. Many theoretical and empirical formulations have been proposed to determine the longitudinal dispersion coefficients. This paper presents an alternative approach to estimate longitudinal dispersion coefficient in natural streams using support vector machine (SVM). Fitness of models has been tested using the observed dispersion coefficient as available in literature. Data corresponding to various natural streams has been used for this purpose. From the published results, it has been shown that the longitudinal dispersion coefficients vary within a wide range [1,9–20,33].

Accurate estimation of longitudinal dispersion coefficient is required in several applied hydraulic problems such as: river engineering, environmental engineering, intake designs, estuaries problems and risk assessment of injection of hazardous pollutant and contaminants into river flows [3,4]. Investigation of quality

ABSTRACT

This paper presents the support vector machine approach to predict the longitudinal dispersion coefficients in natural rivers. Collected published data from the literature for the dispersion coefficient for wide range of flow conditions are used for the development and testing of the proposed method. The proposed SVM approach produce satisfactory results with coefficient of determination = 0.9025 and root mean square error = 0.0078 compared to existing predictors for dispersion coefficient.

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condition of natural rivers by one-dimensional (1D) mathematical model requires the best estimations for longitudinal dispersion coefficient [5]. When measurement and real data of mixing processes in river are available, the longitudinal dispersion coefficient is determined simply, but in rivers that the mixing and dispersing data is not available and these phenomena are not known, should use alternative methods for estimation of dispersion coefficient values [6]. In these cases, because of the complexity of mixing phenomena in natural rivers, the best estimations of dispersion coefficients are not possible and usually these values are determined by several simple regression equations [1]. There are several empirical equations for estimation of longitudinal dispersion coefficient in natural rivers that have presented in next sections [7]. Estimation of longitudinal dispersion coefficient in rivers using equations of Table 1 requires hydraulic and geometry of data sets. These equations are valid only in their calibrated ranges of flow and geometry conditions and for larger or smaller ranges have not good results [7,15].

The main aim of this note is to develop the SVM for dispersion coefficient and assessing the accuracy of these methods in comparisons with real data and at least not at risk developing a new and accurate methodology for dispersion coefficient determination. Therefore, the present study applies a soft computing technique SVM.

2. Support vector regression

When support vector machines were first used for classification, in 1996, another version of SVMs was proposed by Drucker

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Abstract

This study presents Gene-Expression Programming (GEP), an extension of Genetic Programming (GP), as an alternative approach to modeling the stage discharge relationship for the Pahang River. The results are compared to those obtained by more conventional methods, i.e., the stage rating curve (SRC) and regression techniques. Additionally, the explicit formulations of the developed GEP models are presented. The performance of the GEP model was found to be substantially superior to both GP and the conventional models.

Keywords: Flooding, Pahang River, Stage-discharge, GP-GEP, Regression.

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Ab. Ghani, A. & Azamathulla, H.Md. (2011). Gene-expression Programming for Sediment Transport in Sewer Pipe Systems. *Journal of Pipeline Systems Engineering and Practice*, Vol. 2, No. 3, pp. 102-106. ISSN: 1949-1190, DOI: 10.1061/(ASCE)PS.1949-1204.00000076.

Abstract

Old sewerage systems were designed based on empirical rules to minimize sediment problems and a list of codes for self-cleansing sewers. These codes were applicable to noncohesive sediments (typically storm sewers). This study presents gene-expression programming (GEP), which is an extension of genetic programming (GP), as an alternative approach for modeling the functional relationships of sediment transport in sewer pipe systems. A functional relation has been developed using GEP. The proposed relationship can be applied to different boundaries with partial flow. The proposed GEP approach gives satisfactory results ($r^2 = 0.97$ and $MSE = 0.0054$) compared to the existing predictor.

Keywords: Sewers, Sediment transport, Part-full flow, Gene-expression programming, Regression analysis.

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Gene-Expression Programming for the Development of a Stage-Discharge Curve of the Pahang River

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Abstract This study presents Gene-Expression Programming (GEP), an extension of Genetic Programming (GP), as an alternative approach to modeling the stage-discharge relationship for the Pahang River. The results are compared to those obtained by more conventional methods, i.e., the stage rating curve (SRC) and regression techniques. Additionally, the explicit formulations of the developed GEP models are presented. The performance of the GEP model was found to be substantially superior to both GP and the conventional models.

Keywords Flooding · Pahang River · Stage-discharge · GP · GEP · Regression

1 Introduction

Malaysia is virtually free from natural disasters such as earthquakes, volcanoes, and typhoons. The most common natural disaster encountered in Malaysia is flooding. Two major types of floods occur in Malaysia, i.e., monsoon floods and flash floods. The Malaysian Department of Irrigation and Drainage (DID) has estimated that approximately 29,000 km², or 9%, of the total land area and more than 4.82 million

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Gene-Expression Programming for Sediment Transport in Sewer Pipe Systems

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Abstract: Old sewerage systems were designed based on empirical rules to minimize sediment problems and a list of codes for self-cleansing sewers. These codes were applicable to noncohesive sediments (typically storm sewers). This study presents gene-expression programming (GEP), which is an extension of genetic programming (GP), as an alternative approach for modeling the functional relationships of sediment transport in sewer pipe systems. A functional relation has been developed using GEP. The proposed relationship can be applied to different boundaries with partial flow. The proposed GEP approach gives satisfactory results ($r^2 = 0.97$ and $MSE = 0.0054$) compared to the existing predictor. DOI: 10.1061/(ASCE)PS.1949-1204.00000076. © 2011 American Society of Civil Engineers.

CE Database subject headings: Sewers; Sediment transport; Regression analysis; Pipe flow.

Author keywords: Sewers; Sediment transport; Part-full flow; Gene-expression programming; Regression analysis.

Introduction

In sewer networks, deposition of solids occurs occasionally owing to the intermittent nature of flow (Vallini et al. 1996). The larger the deposits remain in the sewer, the more likely it is that the sediment particles will change and eventually become consolidated or cemented, especially during dry weather flows. Such permanent deposits in pipe inverts will change the nature of the velocity and boundary shear distributions, which affects the sediment-carrying capacity and hydraulic resistance of sewers. Problems with sediment transport with no deposition include that by Novak and Nalluri (1978, 1984), May et al. (1986), Mayerle et al. (1991), and Vignati and Ghani (2010).

Sewer system designs must satisfy two major criteria: high-flow and low-flow criteria. During high flows, sewer systems must convey the design discharge. For low flows, sewers should be as free from sediment deposit as possible. Traditionally, a fixed minimum flow velocity for nondeposition, such as 0.6 m/s (ASCE 1970) is used as a low-flow criterion. This criterion may be inadequate because the loading and sediment characteristics vary considerably under different environmental conditions (Vignati and Ghani 2010).

The present study investigates the hydraulic characteristics of flow in channels with a circular cross section with different bed roughness and their effects on sediment transport capacity (Fig. 1) (Vallini and Ab. Ghani, 1996). The pipe channel can be represented by a triangular section, especially at low depths at high depths, the cross section is influenced by the "crowning" effect of the pipe.

through the changes in velocity and shear distribution owing to changes in cross-sectional shapes (Vallini et al. 1996).

Extensive experimental work (Ab. Ghani 1993; Vallini and Ab. Ghani 1996) [5] on bed load transport of noncohesive sediments with no deposition (Fig. 2) was carried out in pipe channels with diameters of 154, 305, and 450 mm covering a wide range of flow depths and sediment sizes and then different bed roughness values as shown in Table 1. The limiting sediment concentrations, $C_L = Q_L/Q$ for the "no deposition" criterion with uniform flow conditions were established for several flow depths (y_c) over each bed roughness.

Multiple Linear Regression—Clean Pipes

The sediment transport rate to channels with a circular cross section or pipe channels depends on many factors, such as flow depth (y_c), bed slope (S), sediment size (d_{50}), density of sediment (ρ_s), kinematic viscosity (ν) of fluid, density (ρ) of fluid, friction factor (λ), pipe diameter (D), and gravitational constant (g).

For the case of bed load transport with no deposition, Ab. Ghani (1993) suggested the following equation to describe bed load transport with a limiting velocity for no deposition relative pipe:

$$\frac{V_c}{\sqrt{gD}} = 3.08D^{0.05} \rho_s^{0.25} \left(\frac{d_{50}}{R} \right)^{0.15} \lambda^{0.25} \quad (1)$$

where V_c = limiting velocity; D = dimensionless grain size $= D_s/\Delta$; $\Delta = (s/\rho - 1)/\rho^{1/2}$; R = hydraulic radius; d_{50} = sediment size; Δ = relative density of sediment in water $= (s/\rho) - 1$; λ = overall friction factor; $\lambda_s = 1.14g^{0.05} \rho_s^{0.25} \nu^{0.15}$; and λ = clear water friction factor of the channel.

Mr. Ghani (1993) has shown that this simple regression equation can provide a good estimation of sediment transport in clean pipes. The above equation yielded $r^2 = 0.95$ and a discrepancy ratio of 1.0. Additional data from the work by Mayerle (1991), May et al. (1986), and Lovelace (1981) were also included in the derivation of Eq. (1) (Fig. 1). The (Q_s/Δ) plot (Fig. 1), where Q is the flow discharge, shows the sediment transporting capacity for different pipe sizes based on Eq. (1).

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Chang, C.K., Azamathulla, H.Md., Zakaria, N.A. & Ab. Ghani, A. (2012). Appraisal of Soft Computing Techniques in Prediction of Total Bed Material Load in Tropical Rivers, *Journal of Earth System Science, Indian Academy of Sciences*. ISSN 0253-4126, In Press.

Mujahid, K., Azamathulla, H.Md., Tufail, M. & Ab. Ghani, A. (2012). Bridge Pier Scour Prediction by Gene-expression Programming, *Proceedings of the Institution of Civil Engineers: Water Management*, ISSN 1741-7589, In Press.

Azamathulla, H.Md. (2012). Gene-Expression Programming to Predict Scour at a Bridge Abutment. *Journal of Hydroinformatics*. ISSN: 1464-7141, DOI: 10.2166/hydro.2011.135. In Press.

Mujahid, K., Azamathulla, H.Md. & Tufail, M. (2012). Gene-Expression Programming to Predict Pier Scour Depth Using Laboratory Data. *Journal of Hydroinformatics*. ISSN: 1464-7141, In Press.

Liew, Y.S., Selamat, Z., Ab. Ghani, A. & Zakaria N.A. (2012). Performance of a Dry Detention Pond: Case Study of Kota Damansara, Selangor, Malaysia. *Urban Water Journal*, IAHR. ISSN: 1573-062x, In Press.

8.3 | INTERNATIONAL CONFERENCE PROCEEDINGS

Nalluri, C. & Ab. Ghani, A. (1993). Shape Effect on Bed Load Transport in Pipes. <i>National Conference on Hydraulic Engineering</i> , Hydraulic Division, ASCE, July 25 – 30, San Francisco, USA, Vol. 2, pp. 1200 - 1205. ISBN: 0872629201
Nalluri, C. & Ab. Ghani, A. (1993). Bed Load Transport without Deposition in Channels of Circular Cross Section. <i>6th International Conference on Urban Storm Drainage</i> , IAHR, September 12-17, Niagara Falls, Canada, Vol. 1, pp. 625-630. ISBN: 1550562533
Nalluri, C. & Ab. Ghani, A. (1994). Sediment Transport in Sewers and Design Implications. <i>National Conference on Hydraulic Engineering</i> ; Hydraulic Division, ASCE, August 1 – 5, Buffalo, USA, Vol. 2, pp. 933-938. ISBN: 0784400377
Nalluri, C. & Ab. Ghani, A. (1994). Sediment Transport in Sewers with and without Deposited Beds. <i>9th Congress of Asia-Pacific Division of IAHR</i> , August 24 – 26, Singapore, Vol. 2, pp. 27-34. ISBN: 9971623544
Nalluri, C. & Ab. Ghani, A. (1995). Sewer Design Options. <i>International Conference on Sewer Solids-Characteristics, Movements, Effects and Control</i> , IAHR, September 5 – 8, Dundee, UK, pp. 223-229. ISBN: 1899796010
Ab. Ghani, A. & Nalluri, C. (1996). Development of Pier-Scour Equations using Field Data. <i>10th Congress of Asia-Pacific Division of IAHR</i> , August 26 – 29, Langkawi, Vol. 1, pp. 295-302. ISBN: 9839429019
Ab. Ghani, A. & Nalluri, C. (1996). Sediment Transport Equations for Self-Cleansing Sewers At Limit Of Deposition. <i>10th Congress of Asian-Pacific Division of IAHR</i> , August 26 – 29, Langkawi, Vol. 1, pp. 339-343. ISBN: 9839429019
Ab. Ghani, A., Amran, N., & Mahibol, J. (1996). Control Of Erosion And Sedimentation In Malaysian Rivers Using Sediment Transport Relationship. <i>Regional Seminar on Integrated River Basin Management</i> ; Malaysian Committee on Irrigation and Drainage (MANCID), September 2 – 5, Malacca, Vol. 3, pp. 4.3.1 - 4.3.15. ISBN: 9839905511
Ab. Ghani, A. & Nalluri, C. (1996). Storm Sewer Design Incorporating Graded Sediment Transport. <i>7th International Conference on Urban Storm Drainage</i> ; IAHR, September 9 – 13, Hanover, Germany, Vol. 1, pp. 283 - 288. ISBN: 3000008608
Fraser, A.G., Ashley, R.M., & Ab. Ghani, A. (2000). Inlet and Sewer Traps for Sediment Control in Stormwater Drainage: A Malaysian Case Study, <i>Joint Conference on Water Resources Engineering & Water Resources Planning and Management</i> , ASCE, July 30-August 2, Minneapolis, USA, Section 39, Chapter 2. ISBN: 0784405174
Ab. Ghani, A., Ariffin, J., Zakaria, N.A., Yahaya, A.S., & Abdul Talib, S. (2002). Error Introduced in Measurements of Bed Load Transport. <i>13th Asia-Pacific Division Congress of International Association of Hydraulic Engineering Research on Hydraulic and Water Resource Engineering in Early 21st Century</i> , August 6-8, Singapore, Vol. 2, pp. 656-660. ISBN: 9812380906
Sinnakaudan, S., Ab. Ghani, A., Chang, C.K., S. Ahmad., M. S. & Zakaria, N, A. (2002). Integrated Triangular Irregular Network (ITIN) Model for Flood Risk Analysis. Case Study: Pari River, Ipoh, Malaysia. <i>13th Asia-Pacific Division Congress of International Association of Hydraulic Engineering Research on Hydraulic and Water Resource Engineering in Early 21st Century</i> , August 6-8, Singapore, Vol. 2, pp. 656-660. ISBN: 9812380906
Sinnakaudan, S., Ab Ghani, A., Chang, C.K. & Zakaria, N, A. (2002). Flood Inundation Analysis Using HEC-6 and ArcView GIS 3.2a. <i>5th International Conference on Hydrosience and Engineering</i> , September 18-21, Warsaw, Poland.
Ariffin, J., Ab. Ghani, A., Zakaria, N.A. & Yahaya, A.S. (2002). Evaluation of Equations on Total Bed Material Load. <i>International Conference on Urban Hydrology for the 21st Century</i> , October 14-16, Kuala Lumpur, pp. 321-327.
Mohd. Sidek, L., Takara, K., Mohd Desa, M.N., Ab. Ghani, A. (2002). Evaluation of Infiltration Engineering and Storage Tank Systems For Improved Stormwater Management. <i>International Conference on Urban Hydrology for the 21st Century</i> , October 14-16, Kuala Lumpur, pp. 535-548.
Abdullah, R., Zakaria, N.A., Ab. Ghani, A., Mohd Sidek, L., & Ainan, A. (2002). Modeling Bio-Ecological Drainage System - A Case Study With Stormwater Management Model. <i>International Conference on Urban Hydrology for the 21st Century</i> , October 14-16, Kuala Lumpur, pp. 572-582.
Mohd Sidek, L., Takara, K., Ab Ghani, A., Zakaria, N.A. & Abdullah, R. (2002). Bio-Ecological Drainage System (BIOECODS): An Integrated Approach For Urban Water Environmental Planning. <i>Seminar on Water Environmental Planning: Technologies of Water Resources Management</i> , October 15 -16.



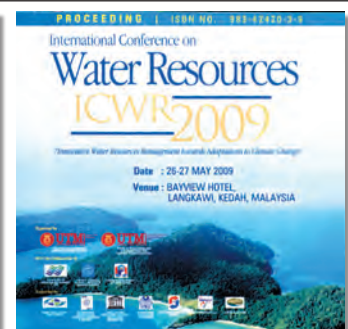
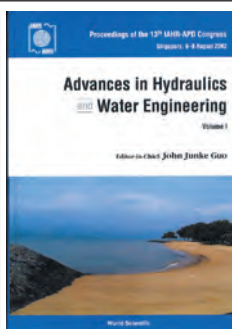


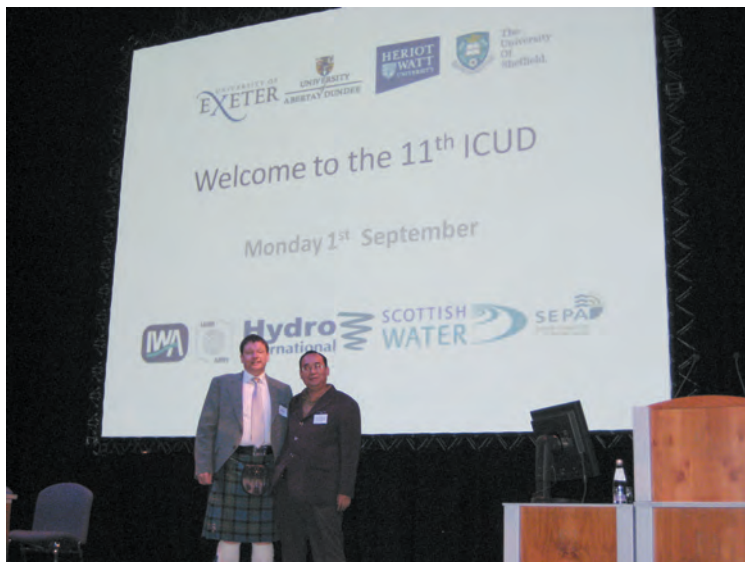
<p>Mohd Sidek, L., Zakaria, N.A., Ab. Ghani, A., & Abdullah, R. (2002). The Use and Development of Bio-Ecological Drainage Systems (BIOECODS) Under Tropical Climate. <i>Water Engineering and Geomatics, Second World Engineering Congress</i>, July 22-25, Kuching, pp. 48-53.</p>
<p>Zakaria, N.A., A. Ab. Ghani, Abdullah, R., Mohd. Sidek, L., Kassim, A. H. & A. Ainan. (2004). MSMA- A New Urban Stormwater Management Manual for Malaysia. <i>6th International Conference on Hydrosience and Engineering (ICHE-2004)</i>, May 30-June 3, Brisbane, Australia. ISBN: 0937099120.</p>
<p>Ab. Ghani, A., Zakaria, N.A., Abdullah, R., Yusof, M. F., Mohd Sidek, L., Kassim, A. H. & A. Ainan. (2004). Bio-Ecological Drainage System (BIOECODS): Concept, Design and Construction. <i>6th International Conference on Hydrosience and Engineering (ICHE-2004)</i>, May 30-June 3, Brisbane, Australia. ISBN: 0937099120.</p>
<p>Ainan, A., Zakaria, N.A., Ab. Ghani, A., Abdullah, R., Mohd Sidek, L., Yusof, M. F. & Wong, L.P. (2004). Peak Flow Attenuation Using Ecological Swale and Dry Pond. <i>6th International Conference on Hydrosience and Engineering (ICHE-2004)</i>, May 30-June 3, Brisbane, Australia. ISBN: 0937099120.</p>
<p>Mohd Sidek, L., Ainan, A., Zakaria, N.A., Ab. Ghani, A., Abdullah, R. & Ayub, K. R. (2004). Stormwater Purification Capability of BIOECODS. <i>6th International Conference on Hydrosience and Engineering (ICHE-2004)</i>, May 30-June 3, Brisbane, Australia. ISBN: 0937099120.</p>
<p>Abdullah, R., Zakaria, N.A., Ab. Ghani, A., Mohd Sidek, L., Ainan, A. & Wong, L.P. (2004). BIOECODS Modelling Using SWMM. <i>6th International Conference on Hydrosience and Engineering (ICHE-2004)</i>, May 30-June 3, Brisbane, Australia. ISBN: 0937099120.</p>
<p>Lau, T.L., Zakaria, N.A., Ab. Ghani, A., Yusof, M. F., Abdullah, R., Mohd Sidek, L. & Ainan, A (2004). Application of BIOECODS for a Government Complex: A Case Study. <i>6th International Conference on Hydrosience and Engineering (ICHE-2004)</i>, May 30-June 3, Brisbane, Australia. ISBN: 0937099120.</p>
<p>Abdul Ghaffar, A.B., Ab. Ghani, A., Zakaria, N.A., Abdullah, R., Abu Hasan, Z. & Chang, C.K. (2004). Determination of Manning's Flow Resistance Coefficient for Rivers in Malaysia. <i>1st International Conference on Managing Rivers in the 21st Century: Issues & Challenges</i>, September 21-23, Penang, Malaysia, pp. 104-110. ISBN: 983-3067-08-5.</p>
<p>Chang, C.K., Ab. Ghani, A., Zakaria, N. A., Abu Hasan, Z. & Abdullah, R. (2004). Measurement of Bed Load Transport for Selected Small Streams in Malaysia. <i>1st International Conference on Managing Rivers in the 21st Century: Issues & Challenges</i>, September 21-23, Penang, Malaysia, pp. 236-241. ISBN: 983-3067-08-5</p>
<p>Darus, A., Ab. Ghani, A., Zakaria, N. A., Abdullah, R. & Chang, C.K. (2004). River Restoration Through Bank Stabilization Using FLUVIAL-12: Case Study of Raia River, Ipoh, Perak. <i>1st International Conference on Managing Rivers in the 21st Century: Issues & Challenges</i>, September 21-23, Penang, Malaysia, pp. 281-285. ISBN: 983-3067-08-5.</p>
<p>Chang, C.K., Ab. Ghani, A. & Abdullah, R. (2004). Effect of a 100-year Flood on River Stability: Case Study of Kulim River. <i>1st International Conference on Managing Rivers in the 21st Century: Issues & Challenges</i>, September 21-23, Penang, Malaysia, pp. 473-478. ISBN: 983-3067-08-5.</p>
<p>Chang, C.K., Ab. Ghani, A., Zakaria, N.A., Abu Hasan, Z. & Abdullah, R. (2004). Sediment Transport Equation Assessment for Selected Rivers in Malaysia. <i>1st International Conference on Managing Rivers in the 21st Century: Issues & Challenges</i>, September 21-23, Penang, Malaysia, pp. 584-590. ISBN: 983-3067-08-5.</p>
<p>Lau, T.L., Ab. Ghani, A., Chang, C.K., Zakaria, N.A. & Abdullah, R. (2004). Performance for Flow Attenuation Using Subsurface Tanks: Case Study in USM Perak Branch Campus. <i>1st International Conference on Managing Rivers in the 21st Century: Issues & Challenges</i>, September 21-23, Penang, Malaysia, pp. 636-642. ISBN: 983-3067-08-5.</p>
<p>Mohd Sidek, L., Takara, K., Ab. Ghani, A., Zakaria, N.A., Abdullah, R. & Desa, M.N. (2004). A Life Cycle Costs (LCC) Assessment of Sustainable Urban Drainage System Facilities. <i>1st International Conference on Managing Rivers in the 21st Century: Issues & Challenges</i>, September 21-23, Penang, Malaysia, pp. 329-343. ISBN: 983-3067-08-5.</p>
<p>Ayub, K.R., Asaari, F.A.H., Abdullah, R., Lau, T.L., Zakaria, N.A. & Ab. Ghani, A. (2004). Water Quality Monitoring at Perai Industrial Park During Wet Season. <i>1st International Conference on Managing Rivers in the 21st Century: Issues & Challenges</i>, September 21-23, Penang, Malaysia, pp. 454-464. ISBN: 983-3067-08-5.</p>
<p>Mohd Sidek, L., Takara, K., Zakaria, N.A., Ab. Ghani, A. & Abdullah, R. (2004). An Assessment of Stormwater Management Practices Using MSMA Manual in Malaysia. <i>1st International Conference on Managing Rivers in the 21st Century: Issues & Challenges</i>, September 21-23, Penang, Malaysia, pp. 479-495. ISBN: 983-3067-08-5.</p>

Mohd Sidek, L., Takara, K., Zakaria, N.A., Ab. Ghani, A. & Abdullah, R. (2004). An Assessment of Stormwater Management Practices Using MSMA Manual in Malaysia. 1 st International Conference on Managing Rivers in the 21 st Century: Issues & Challenges, September 21-23, Penang, Malaysia, pp. 479-495. ISBN: 983-3067-08-5.
Lau, T.L., Ab. Ghani, A., Zakaria, N.A. & Abdullah, R. (2004). Drainage Improvement Work For High Density Development: Case Study of Taman Mangga, Taman Pinang, Taman Sentul and Taman Sentul Jaya. 1 st International Conference on Managing Rivers in the 21 st Century: Issues & Challenges, September 21-23, Penang, Malaysia, pp. 616-623. ISBN: 983-3067-08-5.
Mohd Sidek, L., Takara, K., Ab. Ghani, A. & Desa, M. N. (2005). Bio-Ecological Drainage Systems (BIOECODS) for Effective Stormwater Control in the Tropics. <i>International Conference on Monitoring, Prediction and Mitigation of Water-Related Disasters (MPMD-2005)</i> , January 12-15, Kyoto University, Japan, pp. 625-632. ISBN: 4902712016.
Chang, C.K., Ab. Ghani, A., Zakaria, N.A., & Abdullah, R. (2005). Sediment Transport in Kulim River, Malaysia. <i>XXXI IAHR Congress: Water Engineering for the Future - Choice and Challenges</i> , September 11-16, Seoul, Korea, pp. 1397-1407. ISBN: 8987898245
Yusof, M. F., Zakaria, N. A., Ab. Ghani, A., Abdullah, R. & Chang, C.K. (2005). Infiltration Study for Urban Soil: Case Studies – Butterworth and Engineering Campus, Universiti Sains Malaysia. <i>XXXI IAHR Congress: Water Engineering for the Future - Choice and Challenges</i> , September 11-16, Seoul, Korea, pp. 1154-1162. ISBN: 8987898245
Chang, C.K., Ab. Ghani, A. & Lim, H.W. (2007). Development of Modified Einstein Bed Load Equation for Sandy Stream In Malaysia. 2 nd International Conference on Managing Rivers in 21 st Century: Solutions towards Sustainable River Basins (Rivers'07), June 6-8, Kuching, Sarawak, Malaysia, pp. 533-538. ISBN: 978-983-3067-19-0.
Leow, C.S., Abdullah, R., Zakaria, N.A., Ab. Ghani, A. & Chang, C.K. (2007). Modelling Urban River Catchment: A Case Study of Berop River, Tanjong Malim, Perak. 2 nd International Conference on Managing Rivers in 21 st Century: Solutions towards Sustainable River Basins (Rivers'07), June 6-8, Kuching, Sarawak, Malaysia, pp. 165-171. ISBN: 978-983-3067-19-0.
Ab. Ghani, A., Zakaria, N.A., Chang, C.K. & Ainan, A. (2008). Sustainable Urban Drainage System (SUDS) – Malaysian Experiences, 11 th International Conference on Urban Drainage, August 31-September 5, Edinburgh, UK.
Chang, C.K., Ab. Ghani, A., Zakaria, N.A., Yusof, M.F., Ayub, K.R., Lai, S.H., Hasan, A.M.M., Ainan, A. (2008). Rehabilitation of Ex-Mining Pond and Existing Wetland for Integrated Stormwater Management. 11 th International Conference on Urban Drainage, August 31-September 5, Edinburgh, UK.
Lai S.H., Ab. Ghani, A., Zakaria N.A., Leow, C.S., Chang, C.K. & Yusof, M.F. (2008). Application of SWMM for Urban Stormwater Management: A Case Study with Modelling, 2 nd International Junior Researcher and Engineer Workshop on Hydraulic Structures (JREWHS'08), July 30 - August 1, University of Pisa, Italy.
Liew, Y. S., Selamat, Z. & Ab. Ghani, A. (2009). Performance of Stormwater Drainage System through Dry Detention Pond for Medium Size Housing Development using InfoWorks CS (Case Study: Kota Damansara, Selangor, Malaysia). 8 th International Conference on Urban Drainage Modelling, September 7-12, Tokyo, Japan.
Azamathullah, H.Md., Ab. Ghani, A., Zakaria, N.A. (2009). Prediction of Scour below Flip Bucket using Soft Computing Techniques. 2 nd International Symposium on Computational Mechanics (ISCM II), 12 th International Conference on Enhancement and Promotion of Computational Methods in Engineering and Science (EPMESC XII), November 30 - December 3, Hong Kong – Macau.
Azamathulla, H. Md., Ab. Ghani, A., Zakaria, N.A., Leow, C.S. & Chang, C.K. (2009). Prediction of Scour Around Hydraulic Structure Using Soft Computing Technique. <i>International Conference on Water Resources: Innovative Water Resources Management towards Adaptions to Climate Change (ICWR 2009)</i> , May 26-27, Langkawi, Kedah, ISBN: 34242039.
Lai, S.H., Kee, L.C., Zakaria, N.A., Ab. Ghani, A., Chang, C.K. & Leow, C.S. (2009). Flow Pattern and Hydraulic Characteristic for Subsurface Drainage Module. <i>International Conference on Water Resources: Innovative Water Resources Management towards Adaptions to Climate Change (ICWR 2009)</i> , May 26-27, Langkawi, Kedah, ISBN: 34242039.
Ayub, K.R., Lai, S.H. & Aziz, H.A. (2009). SWAT Application For Hydrologic and Water Quality Modeling For Suspended Sediments: A Case Study of Sungai Langat's Catchment in Selangor. <i>International Conference on Water Resources: Innovative Water Resources Management towards Adaptions to Climate Change (ICWR 2009)</i> , May 26-27, Langkawi, Kedah, ISBN: 34242039.



- Liew, Y.S., Selamat, Z. & Ab. Ghani, A. (2009). Urban Stormwater Drainage System Study using Numerical Modeling. *International Conference on Water Resources: Innovative Water Resources Management towards Adaptions to Climate Change (ICWR 2009)*, May 26-27, Langkawi, Kedah, ISBN: 34242039.
- Hasan, Z.A., Hamidon, N. & Yusoff, M.S. (2010). Hydrologic Modelling Using HEC-HMS for Sungai Kurau Basin, Perak. *International Conference on Water Resources: Innovative Water Resources Management towards Adaptions to Climate Change (ICWR 2009)*, May 26-27, Langkawi, Kedah, ISBN: 34242039.
- Lai, S.H., Kee, L.C., Zakaria, N.A., Ab. Ghani, A. & Chang, C.K. (2010). Subsurface Drainage Module Performance Study in Managing Urban Stormwater, Case Study: Taiping Health Clinic Type 2. *World Engineering Congress 2010 (WEC2010) on Engineering and Technology for Global Stability and Security*, August 2-5, Kuching, Sarawak, pp. 9-14.
- Mohammadpour, R., Ab. Ghani, A., Sabzevari, T. & Siow-Yong, L. (2010). Computation of Flow around Abutments in Compound Open Channel. *Conference on Modern Hydraulic Engineering*, November 27-28, Xian University Technology, Xian, China.
- Hasan, Z.A., Hamidon, N., Zakaria, N.A., Ab. Ghani, A. & Leow, C.S. (2010). Incorporating GIS in Water Resources Modelling: Application of SWAT 2005 Model in Sungai Kurau, Perak and CCHE2D Model in Tasik Harapan. *2nd National Conference on Society, Space & Environment 2009: Towards Sustainable Heritage and Future*, June 2-3, Universiti Sains Malaysia, Penang.
- Zakaria, N.A. (2011). Green Ways of Optimising Natural Resources with Effective Planning for Sustainable Development. *2nd Annual GreenTech Asia Conference: Optimising Green Water & Waste Management for Sustainable Future*, September 26-27, Kuala Lumpur.
- Jamaluddin, A.F., Abu Hasan, Z. & Ab. Ghani, A. (2011). Determining the Effectiveness of Harapan Lake as Flood Retention Pond in Flood Mitigation Effort. *2011 International Congress on Environmental and Computer Science, IPCECS Vol. 19*, pp. 186-192. September 16-18, Singapore. ISSN:2010-0264.
- Zakaria, N.A., Abu Hasan, Z., Leow, C.S., Mohd Kasim, M.Z. (2011). Assessing The Flood and Sediment Control Functions of Lowland Paddy Fields: A Case Study in Muda Irrigation Scheme, Kedah, Malaysia. *MANCID and INWEPF Joint Symposium on Sustainable Agriculture Water Use and Multifunction of Paddy Fields*. November 1-3, Penang, Malaysia.
- Zakaria, N.A., Ab. Ghani, A., Lau, T.L. & Leow, C.S. (2011). Securing Water for Future Generations through Sustainable Urban Drainage Designs: A Peek into the Bio-ecological Drainage System (BIOECODS). *3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011)*, Penang, Malaysia, pp. 29-39, December 6-9, Penang, Malaysia. ISBN: 9789833067350
- Hamidon, N., Abu Hasan, Z. & Harun, S. (2011). Integrated River Basin Management (IRBM): Application of HEC-HMS and SWAT2005 for Kurau River Sub-Basin, Perak. *3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011)*, Penang, Malaysia, pp. 100-109, December 6-9, Penang, Malaysia. ISBN: 9789833067350
- Ahmad, N.A., Ab. Ghani, A., Zakaria, N.A. & Azamathulla, H.Md. (2011). Hydraulic Characteristic for Flow in Swales. *3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011)*, Penang, Malaysia, pp. 183-189, December 6-9, Penang, Malaysia. ISBN: 9789833067350
- Beh, C.H., Ab. Ghani, A., Zakaria, N.A. & Ayub, K.R. (2011). Field Evaluation of BMP Performance in BIOECODS. *3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011)*, Penang, Malaysia, pp. 252-257, December 6-9, Penang, Malaysia. ISBN: 9789833067350





<p>Kee, L.C., Zakaria, N.A., Lau, T.L., Chang, C.K. & Ab. Ghani, A. (2011). Determination of Manning's n for Subsurface Modular Channel. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 266-274, December 6-9, Penang, Malaysia. ISBN: 9789833067350</p>
<p>Jamaluddin, A.F., Abu Hasan, Z. & Ab. Ghani, A. (2011). Effectiveness of Aman Lake as Flood Retention Ponds in Flood Mitigation Effort: Study Case at USM Main Campus, Malaysia. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 277-283, December 6-9, Penang, Malaysia. ISBN: 9789833067350</p>
<p>Chitripolu, R., Lau, T.L. & Ab. Ghani, A. (2011). A Multi Screen Device for the Removal of Urban Litter. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 284-286, December 6-9, Penang, Malaysia. ISBN: 9789833067350</p>
<p>Shaharuddin, S., Ab. Ghani, A., Zakaria, N.A. & Mansor, M. (2011). Biodiversity in Stormwater Constructed Wetlands: Case Study of USM Wetland. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 313-324, December 6-9, Penang, Malaysia. ISBN: 9789833067350</p>
<p>Mohammadpour, R., Ab. Ghani, A. & Azamathulla, H.Md. (2011). Estimating Time to Equilibrium Scour at Long Abutment by Using Genetic Programming. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 369-374, December 6-9, Penang, Malaysia. ISBN: 9789833067350</p>
<p>Sirdari, Z.Z., Ab. Ghani, A. & Abu Hasan, Z. (2011). Estimating Time to Equilibrium Scour at Long Abutment by Using Genetic Programming. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 385-390, December 6-9, Penang, Malaysia. ISBN: 9789833067350</p>
<p>Ab. Ghani, A., Chang, C.K., Leow, C.S. & Zakaria, N.A. (2011). Inferring Digital Flood Mapping from Known Free Data. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 393-401, December 6-9, Penang, Malaysia. ISBN: 9789833067350</p>
<p>Lee, W.H., Lau, T.L. & Abdullah, R. (2011). Flow Estimation by Using Interface Methods in Compound Channel. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 442-447, December 6-9, Penang, Malaysia. ISBN: 9789833067350</p>
<p>Ahmad, B. & Abu Hasan, Z. (2011). Flood Map of Tupai River Using Combined 1D and 2D Modeling. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 491-496, December 6-9, Penang, Malaysia. ISBN: 9789833067350</p>
<p>Pangilan, R.S. & Lau, T.L. (2011). Flooding in Sungai Maka Catchment in the Town of Tanah Merah, Kelantan. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 503-508, December 6-9, Penang, Malaysia. ISBN: 9789833067350</p>
<p>Jamaluddin, A.F., Abu Hasan, Z. & Ab. Ghani, A. (2011). The Impact of Campus Development on the Flash Flood Potential: A Case Study at Watershed USM Main Campus, Pulau Pinang, Malaysia. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 575-581, December 6-9, Penang, Malaysia. ISBN: 9789833067350</p>
<p>Ahamad, M.S.S., Ali, R., Zakaria, N.A., Ab. Ghani, A. & Chang, C.K. (2011). Flood Loss Assessment of the 2003 Muda River Flood. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 601-606, December 6-9, Penang, Malaysia. ISBN: 9789833067350</p>

Leow, C.S., Abdullah, R. & Zakaria, N.A. (2011). Validating Flood Inundation Map for Hydrodynamic Modelling of an Ungauged Catchment. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 607-614, December 6-9, Penang, Malaysia. ISBN: 9789833067350

Ramli, M.S., Abu Hasan, Z. & Koh, H.L. (2011). Application of One-Dimensional Water Quality Modelling for In Stream Dissolved Oxygen. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 648-656, December 6-9, Penang, Malaysia. ISBN: 9789833067350

Shaharuddin, S., Ab. Ghani, A., Chang, C.K. & Zakaria, N.A. (2011). Biodiversity in Stormwater Constructed Wetlands: Case Study of USM Wetland. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 672-680, December 6-9, Penang, Malaysia. ISBN: 9789833067350

Bong, C.H.J., Lau, T.L. & Ab. Ghani, A. (2011). Sediment Deposition Characteristics of Urban Concrete Drains in Kuching City, Sarawak, Malaysia. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 712-720, December 6-9, Penang, Malaysia. ISBN: 9789833067350

Leow, C.S., Ab. Ghani, A., Zakaria, N.A. & Zainal Abidin, R. (2011). Development of Rainfall Erosivity Isohyet Map for Peninsular Malaysia. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 748-756, December 6-9, Penang, Malaysia. ISBN: 9789833067350

Noor Shahidan, N.F. & Abu Hasan, Z. (2011). Application of Mathematical and Physical Modeling to Resolve Sedimentation at Ijok Intake. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 784-790, December 6-9, Penang, Malaysia. ISBN: 9789833067350

Yusof, M.F., Abdullah, R. Azamathulla, H.Md., Zakaria, N.A. & Ab. Ghani, A. (2011). Modified Soil Erodibility Factor, K for Peninsular Malaysia Soil Series. 3rd International Conference on Managing Rivers in 21st Century: Sustainable Solutions for Global Crisis of Flooding, Pollution and Water Scarcity (Rivers 2011), Penang, Malaysia, pp. 799-808, December 6-9, Penang, Malaysia. ISBN: 9789833067350



8.4 REDAC Bulletin



8.5 NEWSPAPER CUTTING

'Bioecods' dijangka tepati sasaran banjir sifar 2010

USM initiates eco-friendly drainage system

Design is 10% cheaper than conventional drains

By Agnes Jamieson
agj@theedustan.com

PERANG, Times (Australia) Sains Malaysia (USM) now branch campus in Transter...

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"Pada masa ini, sistem perparitan di sekitar kawasan itu menggunakan kawasan pembangunan sebelum memasuki sungai berhampiran."

"Sistem itu juga boleh menapis..."

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Centre to help end flood woes by 2006

Combination of approaches including controlled discharge to be used to help tackle problem nationwide



环保功夫做足100分

方家豪 报道

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USM cipta sistem atasi banjir kilat

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14 SATURDAY, DECEMBER 27, 2003

NATION

Bioecods way can solve flash flood

By Lee Keng Fatt
kengf@nsp.com.my

PERANG, Fri. — Introduce Bioecods — bio-ecological drainage system — at housing estates and they will be free of flash floods.

Confident of their system, a team of Universiti Sains Malaysia scientists from the River Engineering and

Urban Drainage Research Centre (Redac), wants to submit their proposal to the Government soon.

Redac director Associate Professor Dr Nor Azizi Zakaria said today Bioecods could also solve river pollution and scarce water supply.

Elaborating, he said Bioecods was designed to combine infiltration, delayed flow, storage and purification as

pre-treatment of water before discharging to man-made wetlands.

"Bioecods represents an alternative approach to the existing Integrated River Basin Management."

"The system also manages water flow rates, reducing the impact of urbanisation on flooding and provides a habitat for wildlife in urban water courses and encourage natural

groundwater recharge," he said.

Nor Azizi said his team would submit its proposal to encourage developers to introduce Bioecods in new housing projects early next month.

"With Bioecods, developers could help the country's target of achieving zero flooding by 2010," he said.

Meanwhile, Dr Nor Azizi said USM would host the first International

Conference on Managing Rivers in the 21st Century here next year.

Themed "Issues and Challenges", the three-day conference will be held at Penang Marriott Beach Resort from Sept 21. Local and foreign researchers and engineers are expected to share expertise on issues and applications methods to solve river-related problems.

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A test-bed for new drainage system

PENANG, Thurs. — Universiti Sains Malaysia's new engineering campus at Trans-Krian on mainland Penang will serve as a test-bed for Malaysia's first environmentally sound drainage system, aimed at making flashfloods a thing of the past.

All eyes will be trained on this bio-ecological drainage system project, whose success will determine the implementation of the system nationwide beginning next year.

This "green" and sustainable which not only alleviates lemons and emits crystal-clear water into rivers, has also saved cost savings to count Australia and Japan where the pilot project, USM

Used water recycled in USM project

NST 5/02/03

NIBONG TEBAL, Tues. — Used water from households is being recycled by Universiti Sains Malaysia in a pilot project to find ways to save water.

The River Engineering and Urban Drainage Research Centre has set up a pilot project on the Bio-Ecological Drainage System (Bioecods) at the university's engineering campus in Trans Krian here.

The centre's director, Associate Professor Dr Nor Azazi Zakaria, said Bioecods water is basically household water that has been processed by the



USM cipta sistem cegah banjir kilat

Ohh Saif Hamzah

GEORGETOWN: Pusat Penyelidikan Kajian dan Penyelidikan (USM) akan membangunkan sistem cegah banjir kilat yang baharu di kampus Trans Krian. Sistem ini akan menggunakan teknologi terkini untuk mengatasi masalah banjir kilat yang berlaku di kawasan perkotaan.

USM akan membangunkan sistem cegah banjir kilat yang baharu di kampus Trans Krian. Sistem ini akan menggunakan teknologi terkini untuk mengatasi masalah banjir kilat yang berlaku di kawasan perkotaan.



DR NOR AZAZI menunjukkan sistem cegah banjir kilat yang baharu di kampus Trans Krian.

Thursdy, June 7, 2007

The Borneo Post

Jabu on causes of river pollution

KUCHING: River pollution in the State mainly consisted of solid wastes, industrial discharges and silt, emanating from various human activity sources, Deputy Chief Minister Daruk Patinggi Tan Sri Alfred Jabu said.

He pointed out that solid wastes were mostly contributed by housing and commercial areas and some construction sites while industries, treatment plants, septic tanks, wet markets, restaurants, food outlets, slaughter and animal farms were the main sources of waste water.

management with control of source, he added.

"The systems will only solve flash flood and water scarcity but also water pollution problems."

By using the systems, Malaysia can prevent such problems, and water shortages, in particular, will be mitigated as rainwater will be re-used," he said in a keynote address on SUDS.

Azazi said in recent years, several pilot projects, including the Bio-Ecological Drainage System (Bioecods), had been carried out at USM's engineering campus in collaboration with the Department of Drainage and Irrigation.

Bioecods comprised three components - ecological swales, biofiltration storage and ecological ponds - which offered an exemplary model for urban storm water management under tropical climates, he added.

On the quantity and quality aspects, he said it had been proven the systems could minimise changes to the hydrological characteristics of catchment area, prevent pollution from contaminating storm water and promote the agency's value USM engineering campus by natural mechanism.

"The results of the study indicate that Bioecods can be viable for water quantity and quality treatment of site run-off," he said.

Industrial discharges and food factory wastes are also significant contributors to the problem.

Industrial wastes and discharges that degraded river water here are mainly produced by wood-based industries, palm oil refining, factories, shipbuilding and engineering works," Jabu said.

He was delivering a keynote address on Managing Multiple Demands On River Resources in Sarawak at the Second International Conference on Managing Rivers in the 21st Century: Solutions Towards Sustainable River Basin here yesterday.

Universiti Sains Malaysia (USM) and the Sarawak Rivers Board are joint organisers of the conference from June 6 to 8.

Jabu, who is also Infrastructure Development and

Another strategy was to bring in corporate giants to support river rehabilitation projects and public awareness programmes, he said.

Earlier, director of USM River Engineering and Urban Drainage Research Centre, Nor Azazi Zakaria, said the sustainable urban drainage systems (SUDS) were the way forward to address three major problems in the country - flash floods, water scarcity and water pollution.

SUDS provided long-term solutions to urban drainage

management with control of source, he added.

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阿兹米卡立将助争取1千万 理大设环保排水研究室

(吉隆) 天然资源及环境部长拿督斯里阿兹米卡立说，他将会协助争取1千万令吉拨款，以便在英属理工科大学工程分校设立环保排水研究室，以更深入研究环保排水系统。

他说，这项系统有别于一般使用的水泥沟渠排水系统，工程耗资和建筑时间方面也能与一般的水沟排水系统媲美。

保持水系统后，对记者这么说。他说，这种排水系统没有使用水泥来建造排水系统，而且所有的水都会渗透到地下的过滤层过滤后，才排到河里，这将会使河流恢复到40年前一般般状况，目前全国已有20条河流受到严重污染，每条河流需要超过10亿令吉治理。

他说，这项排水系统也有减缓水流的功能，下大雨时将有减少水量的效果。这项系统与水泥排水系统不同，主要依靠自然的力量来排水。

阿兹米卡立(左三)希望国内的河流能像理大工程系校园内的河流那么清澈。

他说，若削减稻田灌溉水量，稻农将面对水荒问题。因此，唯一的解决方法，即是兴建水坝来储存水。

他表示，1990年开始，水荒危机的预期已提出，1994年在JICA一项针对北马地区水利研究会上，也提出相关的讨论，同时也建议在吉打及那拉那那地区兴建水坝，然而，至今有关的建设还未获得通过或实行。

他透露，阿拉伯水坝供农业灌溉已不是那么重要，再加上其他用途，阿拉伯水坝不足以应付人民的需求。

阿末夫益恩说，水坝兴建的地点选择不多，适合的还

水利灌溉局已向政府建议将“环保排水系统”的实施，拟定成一项新法令，以替代现有的旧排水系统。

阿末夫益恩说，其实房屋及地方政府部早在2000年已将“环保排水系统”(Manual Saliran Mesra Alam)制定成指南，但却少付诸行动，因此当局希望指南被修定成法令，未来任何发展计划将采用此项新排水系统，最终有效减少城市的“闪电水灾”问题。

他说，所谓的“环保排水系统”是采用收集雨水的方式，将骤然增加的雨水储存起来，较后再将雨水排放至大地及河流，以避免骤然增加的雨水阻塞系统，最终造成闪电水灾。

一连三天的“暴风雨水管理研讨会”是由河流工程与沟渠研究中心主办，主讲人包括阿末夫益恩、美国科罗拉多州大学里罗斯纳教授及理大教授诺阿查兹等，吸引约百人出席。

New urban stormwater management system to curb flash floods

PENANG, Tues. — Malaysians can look forward to seeing benefits from a new water management system



左起阿末夫益恩、诺阿查兹及里罗斯纳，亲切问候来自全国各地的参加者。

建议采完善环保 减缓暴风雨灾害

水利灌溉局向内阁建议修改指南，以采取更完善的环保排水系统措施及高水力的管理，来减缓暴风雨带来的灾害。

水利局：若没建新水

(北海) 随着梅拉河的水源不足应付供州水的需求，预计州将在2010年陷入缺水危机。

水利灌溉局全国副总监阿末夫益恩说，除非州政府有计划增建新的水坝，否则州在未来3年后，将面对严重缺水问题。

他说，由于横贯吉打两地的梅拉河(Sungai Muda)目前的70%水源，主要是作为农作物耕种用途，根本不足以应付州日趋增加的供水需求，若州未

阿末夫益恩认为，最近发生的南马大水灾，是因为出现的罕见暴风雨引发河流泛滥而造成，非常罕见，更是至今在南马发生的最严重水患。

他说：“其实，全世界的河流都会有泛滥问题，任何国家，包括大马都不可能在每条河流兴建治水防洪长堤，除非它频频泛滥成灾，非修建长堤不可。”

他说，要杜绝河流泛滥的方法只有2个，一是兴建防洪长堤，二是兴建水坝，两种方法都耗巨资。

“目前，我们只能采取向人民发出警报的方法，通过迅速疏散群众，将水患祸害减至最低。”

建议实施环保排水系统

水利灌溉局已向政府建议将“环保排水系统”的实施，拟定成一项新法令，以替代现有的旧排水系统。

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Jaga sungai kita

Gaya hidup, amalan penduduk menjadi sumber yang tidak boleh d

HANI DARANI



RASMI... Datuk Patinggi Tan Sri Alfred Jaba yang mewakili Ketua Menteri Sarawak, Datuk Patinggi Abdul Taib Mahmud, dan Datuk Patinggi Datu Abdul Kader Yusoff, Datu Wilson Baya dan Datu Yusoff Yusoff Yusoff...

Jaga sungai kita

bukan penyertaan mereka yang berkepentingan agar kekal dalam usaha menjaga alam sekitar untuk masa depan.

Berikut memaparkan Jabatan Pengurusan dan Saliran memainkan peranan penting dalam pengurusan sumber air di negara ini.

Justeru beliau berharap dengan pelaksanaan IRBM secara menyeluruh dan melalui kempen-kempen yang efektif, ia akan dapat memberi nafas baru kepada sungai yang ada serta menyelesaikan masalah-masalah berkaitan air di negara ini.

Mengenai perisidangan anjuran Lembaga Sungai-sungai Sarawak dan Universiti Sains Malaysia ini, beliau berharap ia memperlengkap pengetahuan dan menyuntik semangat kepada semua yang terlibat untuk menguruskan lembah-lembah sungai secara



Huang Hui of Telebyte RD Instruments, Inc. (2nd right) and Cathleen Chan of the Director General, Department of Irrigation and Drainage Malaysia (left) and Datu P. Muhammad Ismail (left) on how to operate the StreamPro ADCP (Acoustic Doppler Current Profiler) instrument.

Call to protect our river ecosystem



...to be entering a position in which restoration and recovery are increasingly called for as the growing number of cases of "river blindness" is pointed out.

淨水越來越少 保護河流勢在必行

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泰益：主宰萬物生息

【本報訊】泰國總理亞比查育昨日在曼谷表示，泰國將致力於保護其豐富的生物多樣性，並將其作為國家發展的重要支柱。

亞比查育在出席一項由泰國政府主辦的「生物多樣性國際研討會」時，作了上述表示。

他指出，泰國擁有豐富的生物多樣性，這不僅是泰國的財富，也是全人類的財富。泰國政府將致力於保護這些生物多樣性，並將其作為國家發展的重要支柱。

污染水源代價慘

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首長：管理不當對人類生存帶來惡果 河流資源保護非常重要

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號召各界共同推動 保護及保育工作

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河流管理晚宴



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Improve management of river basins: CM

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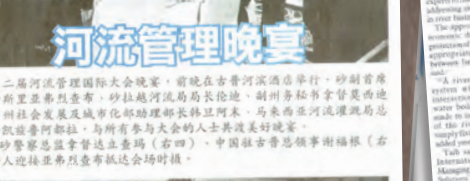
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Water management an urgent issue: Taib

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9.0



BIOECODS@USM
ENGINEERING
CAMPUS



BIOECODS @ SERI MUTIARA

9.1 BACKGROUND

Rapid urban growth in Malaysia over the last 30 years has resulted in increased stormwater flow into receiving waters, increases in flood peaks, and degraded water quality. Traditionally, stormwater management focuses on easing flooding through drainage of stormwater runoff from the urban areas to receiving water bodies. The conventional stormwater drainage has been designed to provide the fastest possible transport (rapid disposal approach) of stormwater runoff out of the catchments into receiving waters. The design philosophy of the conventional drainage system is based on solving localised floods either by transferring excessive flows in drainage system downstream by upgrading the drainage system or relieving localized problems by constructing storm overflows. The consequence of removing the stormwater from the land surface so quickly is to increase volumes and peak rates of flow discharge and finally overloading conventional drainage system. This results in a greater runoff that generally requires expensive enhancement of drainage network to reduce severity and frequency of flooding in urban areas. This also results in a higher pollutant washoff from the urban areas leading to deteriorate water quality in the receiving water bodies (Zakaria et al., 2003; Zakaria et al., 2004; Ab. Ghani et al., 2004).

The conventional rapid disposal approach has reached a limit and that there is a demand for alternative technologies. Therefore there is a need to seek holistic and sustainable solutions not only to mitigate existing flooding problems and water quality degradation but also prevent the occurrences of such problems in new areas to be developed. With the increasing understanding of non point source pollution, which has traditionally included stormwater sources, a holistic design of urban stormwater management systems needs to incorporate the multiple purposes of controlling major and minor floods, as well as stormwater pollution. Government allocations to resolve the current structural work under flood mitigation works such as construction of dam and reservoir, deepening and widening of rivers, increase from time to time. In the Ninth Malaysian Plan (2005-2010) alone, over 70% of the RM5.3 billion budget granted for Department of Irrigation and Drainage (DID) was allocated exclusively for flood mitigation works (DID, 2009). Conventional drainage also contributed to river pollution. During rain event, domestic waste such as solid waste and garbage will easily be carried by water into open drain and subsequently into rivers.

In response to the needs for paradigm shift the way stormwater is managed, the Malaysian government has launched the Urban Stormwater Management Manual for Malaysia or MSMA (DID, 2000) incorporating the latest development in stormwater management that is known as control-at-source approach. From January 2001 onwards, all new development in Malaysia must comply with new guideline that requires the application of treatment devices or facilities (known as Best Management Practices (BMPs) in United States of America or Sustainable Urban Drainage System (SUDS) in the United Kingdom) to control stormwater from the aspect of quantity and quality runoff to achieve zero development impact contribution. This concept of treatments will be able to preserve the natural river flow carrying capacity. The new manual draws on various approach of BMPs/ SUDS now being widely applied worldwide to control the quantity and quality of runoff through detention/retention storage, infiltration facilities, engineered waterway which are capable attenuate flow. The goal of this manual is to provide guidance to all regulators, planners and designers who are involved in stormwater management. It identifies a new direction for stormwater management in urban areas in Malaysia.

9.2 DESIGN CONCEPT

One of such system would be the Bio-ecological Drainage System (BIOECODS), developed by River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia. The BIOECODS is a stormwater drainage system designed with the concept of SUDS in mind, and as a result, is fully complied with the MSMA requirements. BIOECODS is made up of several important components that ultimately form an efficient stormwater treatment train that control runoff quantity and preserve runoff quality. The BIOECODS is designed to provide time for natural processes of sedimentation, filtration and biodegradation to occur, which reduces the pollutant loads in stormwater runoff. In addition, BIOECODS blends easily into their surrounding, adding considerably to the local amenity and/or local biodiversity (Ab. Ghani et al., 2008).

The USM Engineering Campus is located in Mukim 9 of the Seberang Perai Selatan District, Pulau Pinang. The area of the campus is about 320 acres and made up of mainly oil palm plantation land and is fairly flat. The USM Engineering Campus project has taken a series of measures to reduce runoff rates, runoff volumes and pollutant loads by implementing a source control approach for stormwater management as suggested in the MSMA. This include a series of components namely ecological swale, on-line underground storage, and dry ponds as part of the BIOECODS that contribute to the treatment of the stormwater before it leaves the campus (Figure 1). This system was designed to combine infiltration, delayed flow, storage and purification as pre-treatment of stormwater before discharging to constructed wetlands. In addition to source controls, these measures include integrating large-scale landscapes into the development as a major element of the stormwater management system. The concept of the BIOECODS is to integrate with the Ecological Ponds for further treatment of the stormwater runoff. In combination, these increase runoffs lag time, increase opportunities for pollutant removal through settling and biofiltration, and reduce the rate and volume of runoff through enhanced infiltration opportunities.





Figure 1 Aerial View of BIOECODS



Ecological Swale

In order to reduce the drainage footprint of the BIOECODS, as well as to provide additional water treatment, a dual layer conveyance system is introduced. While the surface of the swale is generally not much larger than conventional drain, the total cross section area of the system provides much larger water storage and treatment function than a normal conventional drainage can offer. The surface layer resembles a grassed channel or a swale. Typical swale design, gentle side slope, low gradient and shallow depth applied to this layer. The underground layer, consist of a geosynthetic module enclosed in geotextile. It is connected to the surface layer via a layer of river sand or infiltration media. Figure 2 presents a cross-sectional view of the said ecological swale. Four types of ecological swales were constructed in USM Engineering Campus, namely building perimeter swale, Type A, Type B and Type C depending on the number of modules available underneath the swale.

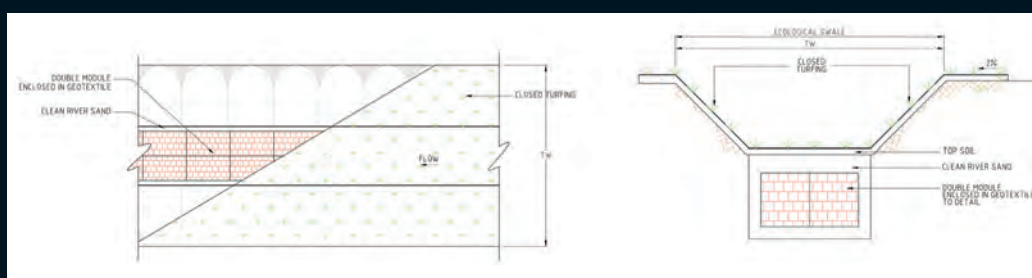


Figure 2 Ecological Swale

As runoff builds up on the surface, it is first infiltrated into the sand layers and then the underground modules. This infiltration provides both quantity and quality treatments to the runoff. First, the infiltration delays flow after which the infiltrated water is stored in subsurface modules. Only after the pool of water generates enough energy will it flow downstream within the module. Along the module, water is lost to adjacent ground through exfiltration of water from the side or bottom of the module. This water will percolate through the ground and either retained as soil moisture or recharge ground water. On the surface, ecological swale attenuates flow by providing larger surface friction through the grass way than the smoother concrete channel.

For water quality treatment, three important processes are involved. First, as water flows into the ecological swale from impervious surfaces, grass on swale surface acts as filter media to trap out particulate pollutants. The aerobic condition of the soil promotes hydrocarbon breakdown. The second treatment involved is the infiltration of water through sand layer and into the module. Infiltration filters out particulates and some smaller solid nutrients that attached to them. The geosynthetic module is manufactured such that the internal structure of the module helps to break up water flow, creating turbulence and therefore increase dissolve oxygen. Finally, both the surface and subsurface flows will combine again by both discharging into the ponds and wetlands system.

Dry Pond

The excess stormwater is also stored on the dry ponds constructed with a storage function. The dry pond is essentially an On-Site-Detention (OSD) pond, which has been integrated with the ecological swale to temporarily store the stormwater runoff. The modular storage tank is placed beneath the detention basin where the stormwater is drained out by infiltration (Figure 3). The outflow path of the storage module is connected to the ecological swale at the lowest point, in order to drain the dry pond system in less than 24 hours. Dry ponds diffuse flow conveyed by swales and the reduced stormwater velocities enable more effective sedimentation, infiltration and evaporative water treatment. The landscape lands are able to infiltrate a substantial portion of the annual surface runoff volume due to the increased soil permeability that is created by the deep and fibrous root systems of the landscape vegetation.



Figure 3 Dry Pond

Detention ponds

Wet pond and detention pond are the community facilities of the BIOECODS (Figure 4). They are primarily designed for attenuating runoff from developed areas through regulated outlet structures. The facility is typically designed to limit discharge to the pre-development stage, while storing water temporarily.



Figure 4 Wetpond (left) and Detention Pond (right)

Wetlands

With respect to the need for water quality improvements, wetlands (Figure 5) is designed as a community treatment facility. As much as 90% of the total volume of annual stormwater runoff will flow through an area supporting growing plant material. Contaminants are removed either by direct absorption into plant tissues (soluble nutrients) or by physical entrapment and subsequent settlement on the wetlands bed. Figure 6 shows an example of wetlands in USM Engineering Campus. Extended exposure to sunlight in a pond will also help to breakdown certain pollutants. Apart from water quality, the wetlands is also designed as a habitat area for biodiversity conservation within a development, supporting species such as small mammals, birds, fish, reptiles and plants.



Figure 5 Constructed Wetlands

Wading River

Wading river (Figure 6) is designed to convey stormwater from the wetlands to recreational pond before discharging to Sungai Kerian. Meanders have been restored in wading river by using graded sediments and gravel. The wading river has two components, i.e. main channel and flood plains. The very large boulders are placed at several locations along the river bank to prevent bank erosion.



Figure 6 A Meandering Wading River Upstream of the Recreational Pond

Recreational Pond

The end product is expected to improve the aesthetic value for surrounding areas with the existence of the “Crystal Clear Blue Water Lake” (Figure 7) at the most downstream end of the drainage system. The water level is maintained in the recreational pond by a 600 mm pipe culvert (Figure 8) discharging into Sungai Kerian.



Figure 7 Recreational Pond



Figure 8 Check valve used to provide flow in one direction only through a culvert

9.3 CONSTRUCTION OF BIOECODS

Materials

Despite its innovative design, the construction materials used to construct a BIOECODS system is rather common and easily available. Common construction materials such as geotextile, river sand, top soil and cow grass are widely used in constructing the system. The only unique material used is the geosynthetic module. Initially designed as underground storage unit in overseas, it has been used innovatively to form an underground drainage network in BIOECODS. Despite the module relatively high price in a decade ago, the continuing popularity and more common use in Malaysia has saw this product being manufactured locally, significantly reducing the cost of material.

Construction Methods

The construction of ecological swale is very simple and does not require highly skilled labours. First, a trench will be dug using backhoe to desired depth after setting out. The trench is then backfilled with river sand to create a desired gradient for the subsurface drain. Then a geotextile is layered onto the sand. Geo-synthetic module is arranged side by side on the geotextile to form a continuous conduit, before the modules are wrapped up in the geotextile. The trench containing the enclosed module is then being backfilled with river sand up to desired invert level. It is then topped up with a thin layer of top soil to sustain vegetation growth. Finally, cow grass is turfed on to the depression to create the surface drainage, i.e grass swale. The entire process involves very minimal machinery. On a daily average, a team of semi-skilled labour of four persons can easily construct 60 - 80 metres of ecological swale. Figure 9 shows the site condition and working procedure of constructing an ecological swale. The construction of dry ponds are very similar to the ecological swale, which involves dual layer system, i.e. underground detention storage units (also using enclosed geosynthetic module) and surface depression which is turfed. Other BIOECODS components, i.e. detention ponds and wetlands are constructed using typical industry methods.



(a) A trench is dug with backhoe and layered with river sand



(c) Trench is backfilled with enclosed module buried within



(b) Module is laid in the trench and wrapped in geotextile



(d) A swale is shaped and topped up with top soil before being turfed



(e) Ecological Swale after Completion

Figure 9 Work Flow of an Ecological Swale Construction

Costs

In 1999, contractors were invited to submit tender for the construction of USM Engineering Campus drainage system package. The contractors were asked to submit tender for two drainage alternatives so the client (USM) could evaluate the feasibility of BIOECODS before actually opting for it. Five contractors submitted their tender and subsequently, USM opted for BIOECODS due to its lower construction cost. Table 1 shows the summary of the estimated cost. Eventually, the cost rose due to addition of new elements and/or variation orders. However, the final cost of the constructed BIOECODS is still 7% cheaper than the proposed cost for conventional drainage (Zakaria, 2011).

Table 1: An Example of Construction Cost for BIOECODS and Conventional Drain

Item	Alternative 1 (Conventional) (RM)	Alternative 2 (BIOECODS) (RM)
1. Total Costs of Drainage System**	5,387,042.51	3,557,582.35
2. Unexpected Cost During Construction (Crossing etc)	-	750,978.47
3. Variation Order for quantity adjustment of materials (20%)	-	703,200.00
Total Construction Cost	5,387,042.51	5,011,760.82
Difference in Total Cost	375,281.69	
Difference in %	7.0	

**note:

1. The shown total cost for alternative 1 is the average cost of 5 submitted tenders.
2. The shown total cost of alternative 2 is the actual cost by the contractor that won the tender.
3. The subsequent costs are recorded through claims by contractor during or after construction.

Mohd Sidek et al. (2004b, 2006) compared life cycle costs of the new environmental-friendly drainage systems based on MSMA and traditional methods of urban drainage design in their study. The method only considers the direct capital and operation and maintenance costs associated with the methods. This simple method can be used to compare the long-term financial feasibility of the MSMA method. The finding of the study was the capital cost for the MSMA method is 5% lower than the traditional method. However, MSMA method has a higher maintenance cost. It is expected the capital cost for MSMA method to reduce as contractors become more familiar with the method and reduces the 'safety margin' placed in the project budget.



9.4 | GREEN BUILDING INDEX (GBI) ASSESSMENT

Sustainable Site Planning & Management (SM) - Stormwater Design With Quantity & Quality Control

The BIOECODS is consistent with objectives of MSMA will focus on the control of both the quantity and quality of urban runoff. BIOECODS are used to cater for the post-development discharge generated from the development area. The proposed drainage system component for both quantity and quality control for this project are:-

- Ecological swale
- Subsurface drainage
- Dry ponds (Bio-retention & OSD)
- Wetlands
- Community Ponds (Wetpond and detention pond)

This system includes a series of BIOECODS components which serves to reduce peak discharge by temporary storage and gradual release of stormwater runoff. This environmental-friendly drainage system practices the "control at source" principle (storage-oriented approach) to simulate the natural hydrological cycle in urban areas by combining infiltration, detention storage, flow attenuation as well as runoff treatment techniques. The reduced post-development runoff hydrograph is typically designed so that peak flow is less than the pre-development peak flow rate. BIOECODS is an innovative concept that will fulfill urban stormwater management objectives to restore each component of the hydrological cycle to its natural level.

Innovation (IN) - Innovation In Design & Environmental Design Initiatives

The stormwater management approach using 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) objectives 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.



Bio-Ecological Drainage Systems (BIOECODS) is an ecologically sustainable solution for flash flood, river pollution and water scarcity using the “control at source” approach. BIOECODS emphasizes the importance of a holistic approach to environmental engineering, landscape architecture and developing, making it unique in the field of stormwater management and innovative urban development. Presently, the project is an example for the development of new urban areas by implementing several components of BIOECODS at once that can meet the concept of Stormwater Management Manual for Malaysia (MSMA) to manage and control stormwater runoff quantitatively and qualitatively at its source. The application of BIOECODS is a new development attempt to solve three major problems commonly encountered in Malaysia namely flash floods, river pollution and water scarcity during dry periods.



9.5 PERFORMANCE OF BIOECODS

Flow Attenuation and Flood Reduction

Since its establishment, BIOECODS has been closely monitored for its hydrological and hydraulic performances. The first BIOECODS system in USM engineering campus has been monitored with sophisticated water quantity and quality equipments to record its performance during rainfall events continuously for almost a decade now. The most significant benefit of BIOECODS is its ability to reduce flow peak and flow volume. The retardation in ecological swale and detention in dry pond, wet pond, detention pond and wetlands have enable BIOECODS to successfully create a stormwater system that mimics natural condition, hence reducing flood risks. Figure 10 shows flow attenuation with detention pond during an event. These are all genuine records gauged by the site monitoring systems. Tables 2 and 3 provide further examples of flow attenuation in swale and pond respectively.

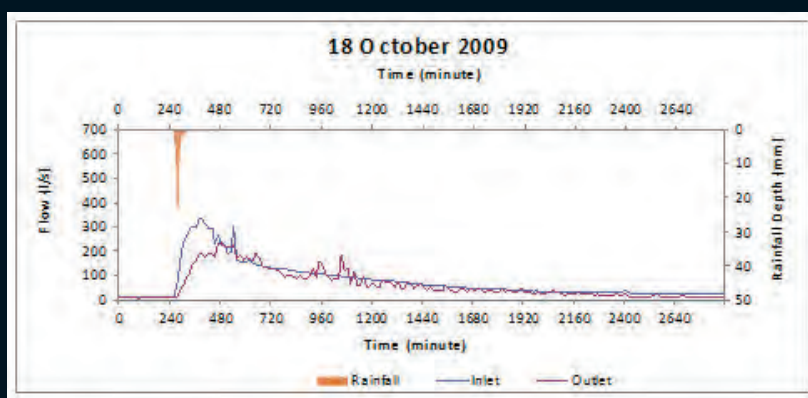


Figure 10 Example of Flow Attenuation by Detention Pond.

Table 2: Example of Ecological Swale Performances for Frequent Rainfall Events (Zakaria, 2011)

Precipitation Event	Average Rainfall Intensity (mm/hr)	Estimated (ARI)	Peak Flow (l/s)		Total Runoff Volume (m ³)		Percentage of Reduction (%)	
			Inlet	Outlet	Inlet	Outlet	Peak Flow	Runoff Volume
24/6/2003	11	3 months	128	91	418.5	246.6	28.9	41.1
30/8/2003	14.5	3 months	59	26	388.8	123.6	55.9	66.6
8/9/2003	13.8	5 years	195	176	4043.1	3043.3	10.0	24.1

Table 3: Example of Detention Pond Performances for Frequent Rainfall Events (Zakaria, 2011)

Precipitation Event	Total Time (mins)	Rainfall Depth (mm)	Rainfall Intensity (mm/hr)	Peak Flow (l/s)		Total Runoff Volume (m ³)		Percentage of Reduction (%)	
				Inlet	Outlet	Inlet	Outlet	Peak Flow	Runoff Volume
14/4/2007	40	23.5	35.3	0.041	0.032	2,214	1,777	21.95	19.74
16/4/2007	70	23.2	19.9	0.034	0.026	1,545	1,200	23.53	22.33
18/10/2009	65	84.6	78.1	0.335	0.235	23,919	18,365	29.85	23.22
11/11/2009	155	171.5	66.4	0.689	0.289	38,859	18,870	50.65	51.44

More detailed observations are recorded in Ainan et al. (2004). The performance of ecological swale was also verified using computer model by Abdullah et al. (2004) using XP-SWMM. In both cases, the authors found that the system performed admirably to attenuate flow from the catchment. Recently, a water balance analysis by Ayub et al. (2010) confirmed that the BIOECODS system actually increases groundwater recharge through infiltration. During drier days, percolated surface water eventually 'resurface' to supply much needed base flow to sustain plants and ecology.

Water Quality Improvements

Apart from water quantity, water quality control of BIOECODS is also being constantly monitored through in-situ test as well as laboratory testing for the common water quality parameters. The final discharge from the system are most of the time conform to Class IIB of National Water Quality Standard published by Department of Environment. It is worth mentioning that the use of this system significantly reduce the pollutant loads especially particulate pollutants, i.e. sediment. For the entire system, TSS was non-detectable, indicating that even if sediments were washed into the system, they are trapped very early on by the ecological swale networks. With the use of detention ponds and wetlands, most biological activities are concentrated in this area, the biological load is rather higher, but still in Class IIB limit. However, the discharge from wetlands is significantly of better quality, indicating the success of biological treatment occurring within the ponds and wetlands. Mohd Sidek et al. (2004a) and Ayub et al. (2005) provide more detailed presentation of the water quality treatment results of BIOECODS.

9.6 CONCLUSIONS

The introduction of Urban Stormwater Management Manual for Malaysia, or MSMA, changed the stormwater management landscape in the country. However, with the increasing need of meeting demands for green technologies and climate change, stormwater engineers are facing a stiffer challenge to produce effective and sustainable drainage system. This requires the need to inject new technologies or innovation into the design of drainage facilities. The Bio-ecological Drainage System or BIOECODS was introduced in 2001. Adopting the concepts of integration, control-at-source and sustainability, BIOECODS paved the way for a promising development in drainage design in Malaysia that fulfils the MSMA criteria. Through innovation in design, the designers introduced the ecological swale, a dual layer conveyance system that minimize drainage footprint but provide additional water quantity and quality treatment. Other components such as dry ponds, wet ponds and wetlands are further evidences of the integration of stormwater facilities into surrounding landscape, adding significant values to otherwise worthless open spaces. The project also overturned the stigma of increased cost due to innovative drainage. Final construction costs proved to be slightly cheaper than a conventional drain. A series of continuous research and monitoring also found that stormwater is effectively controlled in quantity and quality. The system is a living proof for feasibility and multi-benefits of MSMA implementation. BIOECODS also testified that the current stormwater management concept is ready to face the challenges of climate change.

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9.8 BIOECODS PROJECT

Projects	Client / Funded by
Forensic Ward, Hospital Bahagia, Ipoh, Perak	Public Works Department
Health Clinic (Type II), Taiping, Perak	Public Works Department
Pembangunan Tanah Wakaf Khas, Kota Bharu, Kelantan	Kelantan Islamic Affairs and Malay Customs Council (MAIK)
Universiti Malaysia Kelantan, Bachok Campus, Kelantan	Jurutera Perunding Sinar/ Public Works Department
Tasik Raban Resort, Lenggong, Perak	Lenggong District Council
Padang Seri Mutiara, Pulau Pinang	Public Works Department
University Campus, International Universiti College of Automotive Malaysia (IUCAM), Pekan, Pahang	Glenmarie Asset Management Sdn. Bhd.
Student Village, International Universiti College of Automotive Malaysia (IUCAM), Pekan, Pahang	Glenmarie Asset Management Sdn. Bhd.
Mix Development at Seksyen U1, Bandaraya Shah Alam, Selangor	Horsedale Development Sdn. Bhd.
DRB-HICOM Training Centre, Port Dickson, Negeri Sembilan Darul Khusus	DRB-HICOM Berhad

9.9 REFERENCES

1. Ab. Ghani, A., Zakaria, N.A., Abdullah, R., Yusof, M. F., Mohd Sidek, L., Kassim, A. H. & A. Ainan. (2004). Bio-Ecological Drainage System (BIOECODS): Concept, Design and Construction. *6th International Conference on Hydrosience and Engineering (ICHE-2004)*, May 30-June 3, Brisbane, Australia. ISBN: 0937099120.
2. Ab. Ghani, A., Zakaria, N.A., Chang, C.K. & Ainan, A. (2008). Sustainable Urban Drainage System (SUDS) – Malaysian Experiences, *11th International Conference on Urban Drainage*, August 31 – September 5, Edinburgh, UK.
3. Abdullah, R., Zakaria, N.A., Ab. Ghani, A., Mohd Sidek, L., Ainan, A. & Wong, L.P. (2004). BIOECODS Modelling Using SWMM. *6th International Conference on Hydrosience and Engineering (ICHE-2004)*, May 30-June 3, Brisbane, Australia. ISBN: 0937099120.
4. Ainan, A., Zakaria, N.A., Ab. Ghani, A., Abdullah, R., Mohd Sidek, L., Yusof, M. F. & Wong, L.P. (2004). Peak Flow Attenuation Using Ecological Swale and Dry Pond. *6th International Conference on Hydrosience and Engineering (ICHE-2004)*, May 30-June 3, Brisbane, Australia.
5. 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. Special Issue Rivers'04, *International Journal of River Basin Management*, IAHR & INBO, Vol. 3, No. 3, pp. 215-221. ISSN:1571-5124, DOI:10.1080/15715124.2005.9635261.
6. Ayub, K.R., Zakaria, N.A., Abdullah, R. & Ramli, R. (2010). Water Balance: Case Study of A Constructed Wetland As Part of the Bio-Ecological Drainage System (BIOECODS). *Water Science & Technology*, pp. 1931-1936. ISSN: 0273-1223, DOI: 10.2166/wst.2010.473.
7. Department of Irrigation and Drainage or DID, (2000). *Urban Stormwater Management Manual for Malaysia (MSMA)*. DID, Kuala Lumpur.
8. DID (2009). *Compendium: Data and basic information of DID*. DID, Kuala Lumpur.
9. Mohd Sidek, L., Ainan, A., Zakaria, N.A., Ab. Ghani, A., Abdullah, R. & Ayub, K. R. (2004a). Stormwater Purification Capability of BIOECODS. *6th International Conference on Hydrosience and Engineering (ICHE-2004)*, May 30-June 3, Brisbane, Australia. ISBN: 0937099120.
10. Mohd Sidek, L., Takara, K., Ab. Ghani, A., Zakaria, N.A., Abdullah, R. & Desa, M.N. (2004b). A Life Cycle Costs (LCC) Assessment of Sustainable Urban Drainage System Facilities. *1st International Conference on Managing Rivers in the 21st Century: Issues & Challenges*, September 21-23, Penang, Malaysia, pp. 329-343. ISBN: 983-3067-08-5.
11. Mohd Sidek, L., Ab. Ghani, A., Zakaria, N.A., Desa, M.N. & Abdullah, R. (2006). An Assessment of Stormwater Management Practices in Malaysia. *Bulletin Institution of Engineers Malaysia*, pp 8-19, IEM, Kuala Lumpur.
13. Zakaria, N.A., A. Ab. Ghani, Abdullah, R., Mohd. Sidek, L., Kassim, A. H. & A. Ainan. (2004). MSMA- A New Urban Stormwater Management Manual for Malaysia. *6th International Conference on Hydrosience and Engineering (ICHE-2004)*, May 30-June 3, Brisbane, Australia. ISBN: 0937099120.
14. Zakaria, N.A., Ab. Ghani, A., Abdullah, R., Mohd Sidek, L. & Ainan, A. (2003). Bio-Ecological Drainage System (BIOECODS) for Water Quantity and Quality Control. *International Journal of River Basin Management*, IAHR & INBO, Vol. 1, No. 3, pp. 237-251. ISSN:1571-5124, DOI:10.1080/15715124.2003.9635210.
15. Zakaria, N.A. (2011). Green Ways of Optimising Natural Resources with Effective Planning for Sustainable Development. *2nd Annual GreenTech Asia Conference: Optimising Green Water & Waste Management for Sustainable Future*, September 26-27, Kuala Lumpur.

10.0



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