Rehabilitation of Ex-Mining Pond and Existing Wetland for Integrated Stormwater Management

C.K. CHANG[1*], A. AB. GHANI[1], N.A. ZAKARIA[1], M.F. YUSOF[1], K.R. AYUB[1], S.H. LAI[1], A.M.M. HASAN[2], A. AINAN[2]

[1]*River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia, Engineering Campus, 14300 Nibong Tebal, Pulau Pinang, MALAYSIA*
[2]*Urban Drainage Division, Department of Irrigation and Drainage Malaysia, Jalan Sultan Salahuddin, 50626 Kuala Lumpur, MALAYSIA*

**Corresponding author, e-mail* redac10@eng.usm.my

ABSTRACT
A study on rehabilitation of ex-mining pond and existing wetland for integrated stormwater facilities has been carried out in Malaysia. The study focused on the quantity and quality control of urban stormwater runoff by incorporating the abandoned pond structures in the stormwater facilities that will be constructed. The proposed stormwater facilities are based on the integrated Sustainable Urban Drainage System (SUDS) concept which focuses on long term environment and social factors. It takes account of the quantity and quality of runoff, as well as the amenity value of surface water in the urban environment. Based on the proposed design, routing of flow through the stormwater facilities has been conducted using the level pool method, and the preliminary results show that the rehabilitated ex-mining ponds and wetland are able to reduce the peak discharges effectively.

KEYWORDS
Rehabilitation; ex-mining pond; wetland; stormwater management; SUDS, BMPs

INTRODUCTION
Urbanization and the increase in impervious surfaces typically associated with urban development have consistently been shown to result in degraded aquatic ecosystems. These effects are a function of increased stormwater runoff volumes, surface erosion and pollutants loading across a watershed due to the efficient routing of stormwater off impervious surfaces and into a storm sewer system that ultimately discharges into a receiving water body. These elevated volumes impact stream ecosystems through amplified flow rates which increase bed and bank erosion, rapid and efficient pollutant transport and an increase in nuisance flooding in urban watersheds.

In order to overcome the above problems, the Department of Irrigation and Drainage (DID), Malaysia has produced a new urban drainage manual, known as Stormwater Management Manual or SWMM in year 2000 (DID, 2000). This manual emphasized on the use of Best Management Practices (BMPs) such as the "control at source" approach to control stormwater quantity and quality, and to achieve Zero Development Impact Contribution.

In conjunction with the effort of DID in solving the urban stormwater problems such as flash flood, pollution, and etc. and realizing that Malaysia has many abundant ex-mining ponds and wetland which can be fully utilized for integrated stormwater management, this study is carried out to explore the potential of these ponds structures to be rehabilitated and incorporated in the urban stormwater facilities that will be constructed for quantity and quality control of urban stormwater.

REVIEW

Integrated Sustainable Urban Drainage System (SUDS) with BMPs is a concept that includes long term environmental and social factors in decisions about drainage. It takes account of the quantity and quality of runoff, as well as the amenity value of surrounding area in the urban environment.

SUDS is made up of one or more structures built to manage surface water runoff. They are used in conjunction with good management of the site, to prevent flooding and pollution. There are four general methods of control which consist of (1) filter strips and swales; (2) filter drains and permeable surfaces; (3) infiltration devices; (4) wetlands, basins and ponds. The controls should be located as close as possible to where the rainwater falls, providing attenuation for the runoff. SUDS do not operate as a series of isolated drainage devices, but should be designed and operated holistically. Each component adds to the performance of the whole drainage system which works in series, with settling pond to take out coarse sediments, followed by a filter strip to further treat the runoff; and the runoff is polished in a wetland before returning to the environment. The range of options available allows the surface water to be drained in a variety of equally acceptable ways. Further information on the theory and concept of BMPs, and design of SUDS including pond and wetland for quantity and quality control can be obtained from ART (1997), Maryland State (2000), CIRIA (2000, 2001, 2004).

Most of the stormwater ponds monitored in the past were relatively small in size and simple in design. Moreover, these ponds seldom possessed the forebays, aquatic benches, greater volumes, extended detention, pondscaping and other design features now routinely prescribed by many local stormwater agencies. A study had been carried out in Austin, Texas to evaluate stormwater pond performance in pollutant removal. The stormwater pond at St. Elmo served a 27.1 acre catchment that had more than 66% impervious cover, most of which was either street or parking lot. The surface area of the pond was 1.65 acres, with about 40% devoted to shallow wetlands, and 60% allocated for deeper pools. Forebays were located at the primary stormwater inlets, and berms were used to extend the flow path and prevent runoff from short-circuiting through the pond. The pond also provided extended detention storage above the pool, with a one to three day draw down time after a storm. Combination of the permanent pool and extended detention storage provided about 1.8 watershed-inches of storage quality treatment. Overall, the hydraulic retention time in the pond ranged from two to 70 days, with an average of about a month.

The shallow areas in the pond were planted with spike rush (*Eleoarchis spp.*), Bulrush (*Scirpus*), Duck Potato *(Saggitaria)* and other aquatic plants to conceal changes in water levels. The results obtained from water sampling collected at inlets and outlet of the pond, and data analysis following the exact standards of the City of Austin Drainage Utility have shown that the St. Elmo pond provided a very high rate of pollutant removal, with more than 90% removal of total suspended solids and bacteria. Nutrient removal was also quite strong, with exceptional removal of total phosphorus (87%) and dissolved phosphorus (66%). Removal of various forms of nitrogen ranged from 40 to 90%, as well. However, the removal of metals was not as promising, ranging from 30 to 60%. Overall, the St. Elmo pond consistently achieved removal rates approximately 20% above the national median removal rates for wet ponds. The high level of stormwater treatment achieved at St. Elmo was attributed to its enhanced pond design features and large permanent pool. These resulted in unusually long hydraulic residence times that allowed settling, algal uptake and other pollutant removal processes to occur.

On the other hand, wetlands have been found to be effective in treating BOD, TSS, N and P as well as for reducing metals, organic pollutants and pathogens (Davis, 1994). According to Reddy and DeBusk (1987), the principal pollutant removal mechanisms in constructed wetlands include biological processes such as microbial metabolic activity and plant uptake as well as physico-chemical processes such as sedimentation, adsorption and precipitation at the water-sediment, root-sediment and plant-water interfaces. Simeral (1998) describes that a properly constructed wetland that is designed to work with the topography has many advantages including: a high level of treatment, low operational expenses, low construction costs, reduced or eliminated odor problems, handling of varying wastewater loadings, reduced land costs for land application of wastewater, ascetic appeal, and providing a wildlife habitat. The main disadvantage of the system is the continuous water supply requirement. Other disadvantages would be that certain soil features and topographies make wetlands expensive to construct and operate. An overload of solids or ammonia levels will destroy the system.

Schueler et al. (1992) have reported based on twenty stormwater wetland sites in the mid-Atlantic region United States of America that the long term pollutant removal rates were found to be 75% for total suspended solids, 45% total phosphorus, 25% total nitrogen, 15% organic carbon, 75% lead and 50% zinc. Nakamura et al. (1999) carried out field experiments based on three wetlands in Japan, his results revealed that the wetlands are able to remove nitrogen efficiently with a removal rate of 66% - 77% percentage. Elder & Goddard (1996) study the Jackson Creek Wetland in reducing sediment and nutrient inflow to eutrophic Delavan Lake, results of the study show that the Jackson Creek Wetland retained suspended sediment effectively and consistently, trapping 46 percent of the input load during the study period. However, the wetland apparently is not continuously effective as a site for nutrient retention, even in its current status as a relatively young and highly productive ecosystem. This finding, although illustrating some limitation of the wetland as a nutrient sink, does not necessarily conflict with the general concept of nutrient retention in the wetland.

More recently, The Bio-ecological drainage systems (BIOECODS) constructed at USM Engineering Campus has taken a series of measures to reduce runoff rates, runoff volumes and pollutant loads by implementing a source control approach. This system includes a series of components namely ecological swale, on-line underground storage, and dry ponds that contribute to the treatment of the stormwater before it leaves the campus. 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 bio-ecological drainage systems (BIOECODS) is to integrate with the Ecological Ponds including a wet pond, detention pond, wetland and a recreational pond 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 (Zakaria et al. 2003).

DESCRIPTION OF THE STUDY AREA

The study area reported in this paper is located at Daerah Kinta, Ipoh, the capital city of Perak state in Malaysia as illustrated in Figure 1. It covers an area of 88 acres, and the project area can generally be divided into several categories which include open spaces, ponds, earth drains and also wetland or swampy area. The existing stormwater facilities system in the project area is not well designed and lack of maintenance especially on the earth drain system. In spite of this, the abundant swampy area has created good ecological environment towards natural wetland system in the project area. The contribution of grey water from existing residential areas next to the study area and stormwater from the study area has caused degradation of water quality in the existing stormwater facilities.

There are two ex-mining ponds, namely Pond 1 and Pond 2 are available in the study area. The details and the capacity of the pond system are given in Table 1. Both of the ponds receive stormwater from the administrative and workshop buildings. Excess water from this pond is discharged to the existing earth drain at the downstream of the ponds. Flow routing had been carried out by applying the survey data and some inventory data obtained from the study area to check the capacity for the existing pond system against 10-year and 50-year storm. The results show that the ex-mining ponds have enough capacity to function as a storm water facility (up to 50-year ARI (Average Recurrence Interval) storm. event) under the current conditions in the study area.

There are two catchments (17400m^2 and 291000m^2) that contribute runoff to the study area before discharging to Kinta River. Surveys on the earth channel cross section have been carried out to determine precisely the layout and details of the existing earth channel. The existing earth channel capacity in the study area for current land use were checked against runoff discharge of 5 and 10-year ARI for minor storm system and 50-year ARI for major storm system by using the Rational Method. The results were then compared with the bank-full capacity computed by using Manning Equation of the existing earth channel cross-sections which were measured from the previous survey. The result shows that the existing earth channels are under-designed and inadequate to cater for all ARI concerned. Thus, upgrading of the earth channel is necessary to cater for the design rain storm.

Two existing wetlands with areas of 29556 m^2 and 2341 m^2 respectively are stretched along the eastern border of the site. These wetlands are bounded by berm around the wetland. Several useful plant species are found in these wetlands such as *Phragmites karka, Hanguana malayana, Scirpus grossus, Monochoria hastata* and *Saccharum spontaneum*. However, several noxious weed species are also discovered in the study area including *Eichornia crassipes* and *Limnocharis flava*. These harmful species would dominate the ponds and lakes besides blocking water courses and the water becomes foul due to the large mass of decomposing leaves. Moreover, the species can spread rapidly and if not being controlled, they can significantly reduce its intended functionality or other useful plants.

Figure 1. Location of Project Area.

Table 1. Capacity of Existing Pond System.

	Ex-Mining Pond 1	Ex-Mining Pond 2
Area (m^2)	11,642.47	6,110.89
Average Depth of Pond (m)	4.07	3.53
Average Water Depth (m)	3.72	3.01
Max. Volume of Pond (m^3)	47,384.87	21,571.44
Dead Storage Volume (m^3)	43,310.00	18,393.78
Storage Volume, V_{10} (m^3/s)	19.12	4.99
Storage Volume, V_{50} (m^3/s)	23.55	6.65
Outflow Capacity, Q_{10} (m^3/s)	0.15	0.13
Outflow Capacity, Q_{50} (m^3/s)	0.18	0.16
Stage Level Discharge, Q_{10}	RL +30.77 m	RL +30.42 m
Stage Level Discharge, Q_{50}	RL +30.78 m	RL +30.43 m
Average Existing Ground Level	RL +31.45 m	RL +31.60 m

Water quality monitoring was carried out to evaluate the level of water pollution of the stormwater and grey water in the study area. It was found that grey water from the nearby buildings and developing housing area within the study area has been discharged into the existing drain and other available waterways directly without any control and proper treatment. These had produced the toxic material and contaminated the waterways as well as led to water pollution in the drain, ponds and river. Based on the water samples collected at several sampling monitoring station in the study area, 23 water quality parameters including PH, Dissolved Oxygen (DO), Suspended Solid (SS), Ammoniacal Nitrogen (NH_3-N), etc. Have been analysed. The results show that the water quality in the study area is of Class IIB based on the Water Quality Index for River in Malaysia or Standard B based on the EQA Standard, which is suitable for domestic use only.

REHABILITATION OF EX-MINING PONDS AND WETLAND

The existing condition of storm water facilities in the Project Area have to be rehabilitated and upgraded in order to cater for the stormwater as well as to improve the water quality in the study area. Figure 2 shows the layout and details of the stormwater facilities proposed in the study area. The storm water facilities consisted of several types of ponds, conveyance system, and wetland. Most of these components will be functioning as storm water quantity and quality control, as well as for recreational purpose as describe below:

i. The Ex-mining Pond 1 and Pond 2 will be rehabilitated and designed for stormwater quantity and quality control for storm event of 10-year ARI (minor) and 50-year ARI (major)

ii. Two components of runoff conveyance structure are included in the proposed stormwater facilities, namely engineered waterway, and wading river. These components will convey stormwater to the downstream receiving water body ie. River Kinta..

iii. A wetland will be constructed (Figure 3) with an inlet connecting to the existing natural wetland. The constructed wetland consists of a forebay, inlet zone, macrophyte zone and an open water zone, which covers a catchment area of 53.54 hectare. It is designed to cater for flows of 3 months ARI to 10 years ARI and it will operate in a three-phase system, where the water move from forebay then flows through both emergent (low marsh and high marsh) and open water area (micro pool). The constructed wetland will be planted with the existing wetland species. However, other wetland species such as *Typha augustifolia*, *Lepironia articulata* and *Eleocharis dulcis* (Table 4) will also be planted to increase the effectiveness in pollutant removal.

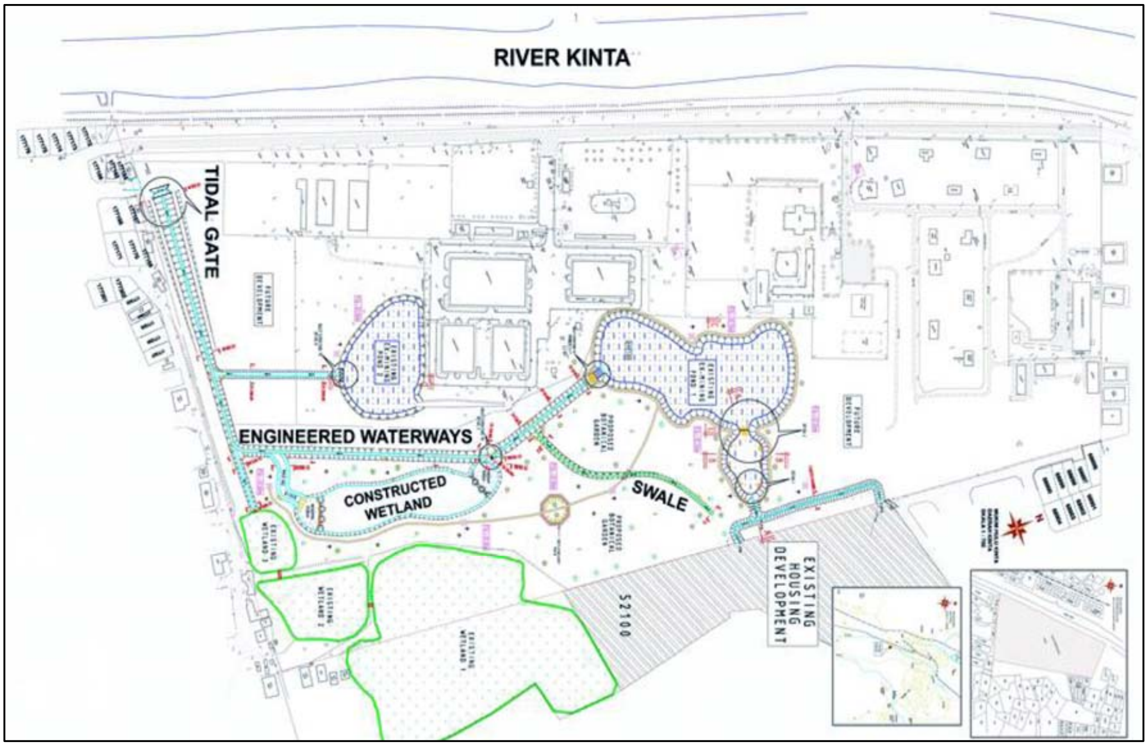

Figure 2. Layout and details of the stormwater facilities proposed in the study area.

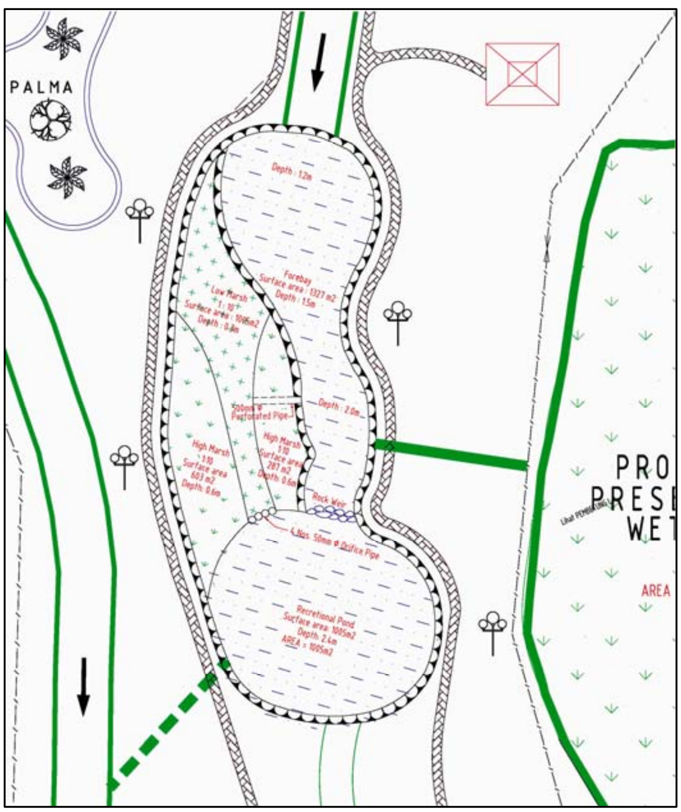

Figure 3. Layout of constructed wetland for quality control of stormwater.

Table 4. Proposed Wetland Species to be Planted in Constructed Wetland

No	Wetland Species	Functions	Water Depth
1	 *Eleocharis dulcis*	• Removal and biodegradation of chemical pollutants in water; • Physical removal of suspended solids	0 – 0.3m (High marsh)
2	 *Hanguana malayana*	• Bank protection • Reduces suspended solids and chemical pollutants • Biodegrades organic pollutants in water	0 – 0.3m (High marsh)
3	 *Scirpus grossus*	• Reduces suspended solids and chemical pollution • Biodegrades organic pollutants in water	0.3 – 0.6m (Low marsh)
4	 *Lepironia articulata*	• Reduces suspended solids and chemical pollutants • Biodegrades organic pollutants in water	0.3 – 0.6m (Low marsh) 0.6 – 1.0m (Deep marsh)
5	 *Typha augustifolia*	• Reduces suspended solids and chemical pollutants • Biodegrades organic pollutants in water	0.3 – 0.6m (Low marsh) 0.6 – 1.0m (Deep marsh)

Based on the design, routing of flow through the stormwater facilities has been conducted using the level pool method. Samples of hydrographs obtained for the rehabilitated ex-mining ponds 1 and 2 at both inlet and outlet are as shown in Figures 4 to 5. These results illustrated that the rehabilitated ex-mining ponds are able to attenuate the flow effectively, and able to reduce the peak flow up to 61.4% and 56.2% for pond 1 and pond 2, respectively. The project is currently undergoing the construction phase, it is strongly believed that upon completion, the urban stormwater facilities are able to contribute in improving the water quality in the study area.

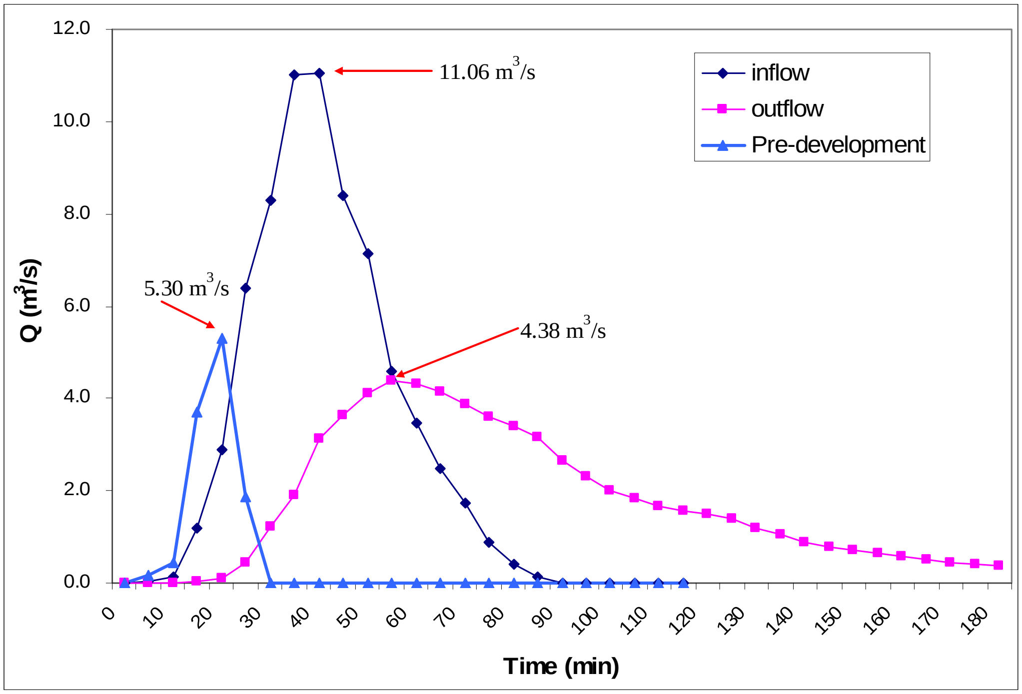

Figure 4. Inflow-Outflow Hydrograph for Ex-Mining Pond 1 under 100-Year ARI design rainstorm.

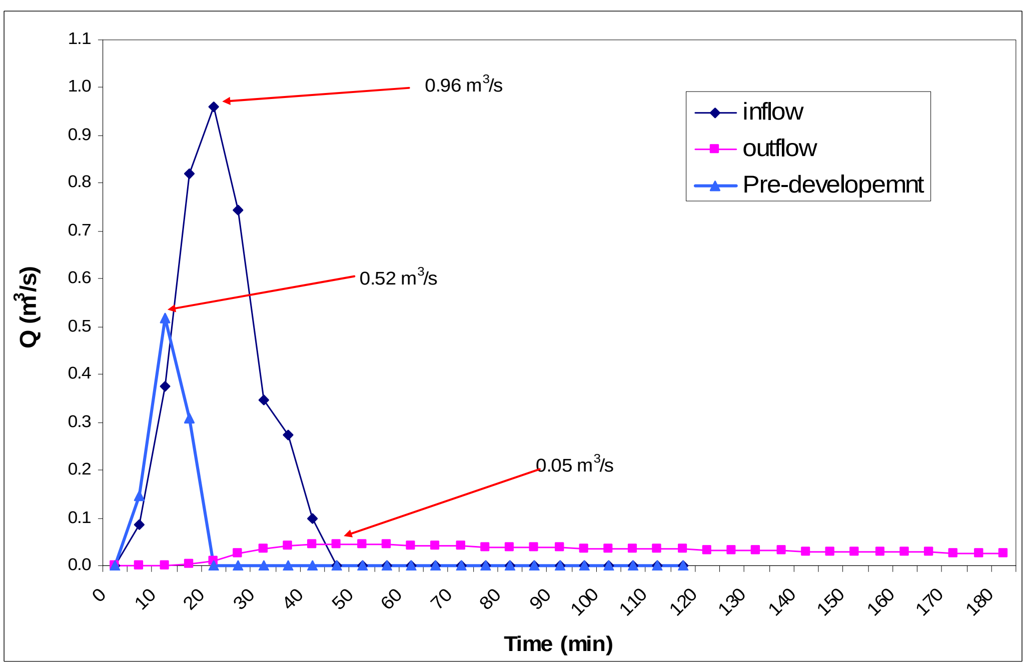

Figure 5. Inflow-Outflow Hydrograph for Ex-Mining Pond 2 under 50-Year ARI design rainstorm.

CONCLUSIONS

The preliminary results obtained from this study are encouraging and promising, it is therefore can be accepted that the ex-mining pond and existing wetland available should be fully utilized for Integrated Stormwater Management. However, further study needs to be carried before a final conclusion can be drawn.

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