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Hydrological and sediment-transport systems within the Putrajaya Wetlands, Putrajaya

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Abstract: The Putrajaya Lake and Wetlands complex is the main and the biggest component of Putrajaya, the new Malaysian Government Administrative Centre. The lake, which covers an area of about 7.0 km^2, was artificially created to become the aesthetic centre of Putrajaya. Maintaining the water quality of the lake is the most important aim of the lake management programme. To maintain the good quality of water and aquatic life within the lake, the Putrajaya Corporation (Perbadanan Putrajaya) has created a monitoring and research unit, comprising the KLCC-UH (KLCC-Urusharta Sdn. Bhd., a private company) and a research team, to continuously monitor, investigate and report on all aspects of the Lake and Wetlands. This paper describes and discusses the results of the hydrological and sediment monitoring program for the months of October 2001 until May 2002 for Lake 1A and the Wetlands, focusing on the hydrological and sediment-transport systems within the wetlands.

Data on rainfall, water-discharge, TSS (Total Suspended Solid) and TSS-discharge for the months of October 2001 to May 2002 were analysed. The rainfall pattern shows two prominent modes, one around the month of November 2001 and another around the months of April-May 2002. The water discharge trends measured at all the wetland arms show prominent peaks at around November 2001 and April-May 2002 and closely correspond to the rainfall pattern. The results clearly indicate that water-discharge at the northern Putrajaya Wetlands is very much governed by rainfall.

The TSS concentration trends recorded at the different wetland arms show peaks which corresponds to the water-discharge peaks for the period October 2001 to May 2002. Erosion and transportation of earth's surface material becomes more rapid during intensive events such as flooding and storms. High rainfall coupled with the availability of fresh sediment sources in upstream catchment areas, due to land clearing results in greater erosion and sediment yield, and sediment discharge in the wetland cells.

The TSS-concentration graphs also display other peaks during periods of low rainfall between November 2001 to April 2002, and these peaks indicate that there are other factors involved in determining the volume of TSS entering the wetlands. The TSS-discharge trends at the different wetlands closely resemble the water-discharge trends (and not the TSS-concentration trends). Water is the main medium that transports the TSS, downstream, along the wetlands. Thus, although the concentration of TSS may be high during months where rainfall is low, only a small volume is transported downstream, along the wetland cells, due to the low water-discharge volume.

Abstrak: Komplek Tasik dan Wetland Putrajaya adalah merupakan komponen yang utama dan terbesar di Putrajaya, yang merupakan pusat pentadbiran Kerajaan Malaysia yang baru. Tasik yang meliputi kawasan seluas 7.0 km^2 ialah tasik buatan manusia yang telah dibangunbina untuk menjadi pusat tumpuan estetika Putrajaya. Oleh itu, program pengurusan tasik memberi tumpuan utama dalam penjagaan kualiti air di tasik. Untuk memelihara dan mengekalkan kualiti air yang tinggi dan kehidupan akuatik yang baik didalam tasik, pihak Perbadanan Putrajaya (Putrajaya Corporation) telah membentuk suatu unit pengawasan dan penyelidikan, yang terdiri dari KLCC-UH (KLCC-Urusharta Sdn. Bhd., sebuah syarikat swasta) dan satu kumpulan penyelidik. Unit ini ditugaskan untuk mengawas, menyelidik dan melaporkan secara berterusan semua aspek Tasik dan Wetland. Kertaskerja ini memperihal dan membincangkan hasil keputusan program pengawasan hidrologi dan sedimen bagi bulan Oktober 2001 sehingga Mei 2002 untuk Tasik dan Wetland, dengan memberi tumpuan khusus kepada sistem hidrologi dan pengangkutan sedimen didalam wetland.

Analisa dilakukan ke atas data kerpasan (ukuran hujan), luahan air, TSS (Total Suspended Solid — Jumlah Pepejal Terampai) dan luahan TSS dari bulan Oktober 2001 sehingga Mei 2002. Corak hujan mempamerkan dua mod yang tertonjol, satu disekitar bulan November 2001 dan satu lagi disekitar bulan April-May 2002. Ukuran luahan di semua sayap wetland juga mempamerkan mod yang tertonjol disekitar bulan November 2001 dan satu lagi disekitar bulan April-May 2002, mirip kepada corak hujan. Keputusan-keputusan ini menunjukkan bahawa luahan air di Wetland Putrajaya bahagian utara adalah dikawal oleh hujan.

Corak graf kepekatan TSS yang direkod dari sayap wetland yang berbeza menunjukkan kemuncak-kemuncak yang berpadanan dengan corak luahan air bagi Oktober 2001 sehingga Mei 2002. Hakisan dan pengangkutan bahan-bahan tanih diperhebatkan semasa peristiwa-peristiwa keamatan tinggi seperti banjir dan ribut yang berkait dengan hujan lebat Hujan lebat di kawasan-kawasan di mana sumber enapan baru tersedia akibat kerja-kerja punggahan tanah, seperti di bahagian hulu Putrajaya akan mengakibatkan hakisan dan pengeluaran sedimen yang lebih tinggi, dan luahan sedimen yang meningkat di wetland. Graf-graf kepekatan TSS juga menunjukkan kemuncak-kemuncak lain pada ketikan kadar

hujan lebih rendah antara bulan-bulan November 2001 sehingga April 2002. Kemuncak-kemuncak ini menunjukkan bahawa terdapat factor-faktor lain yang mengawal kemasukan isipadu TSS kedalam wetland.

Corak graf luahan TSS mirip kepada corak luahan air (dan bukan corak kepekatan TSS). Air adalah merupakan media pengangkut TSS yang utama ke hilir, melalui wetland. Oleh itu, walaupun kepekatan TSS tinggi semasa hujan adalah rendah, hanya isispadu yang sedikit dari TSS ini diangkut kehilir, sepanjang wetland, disebabkan kadar luahan air yang rendah.

INTRODUCTION

The Putrajaya Lake is the main and the biggest component of Putrajaya, the new Malaysian Government Administrative Centre which is located about 40 km south of Kuala Lumpur. The lake, which covers an area of about 7.0 km^2, was artificially created to become the aesthetic centre of Putrajaya, providing a focal point for design, leisure and recreational activities.

Maintaining the lake water quality is the most important aim of the lake management programme. In general, the water quality is expected to satisfy both aesthetic and health-related objectives for aquatic life, primary and secondary contact. Many factors contribute and determine the water quality in a lake — the main factors include the pH value, the algae population, the dissolved oxygen, nitrogen, phosphorus, suspended sediment and the bedload sediment.

To maintain this high quality of water and aquatic life within the lake, the Putrajaya Corporation (Perbadanan Putrajaya) has created a monitoring and research unit, comprising the KLCC-UH (KLCC-Urusharta Sdn. Bhd., a private company) and a research team, to continuously monitor, investigate and report on all aspects of the Lake and Wetlands. This paper describes and discusses the results of the hydrological and sediment monitoring program for the months October 2001 until May 2002 for Lake 1A and the Wetlands, focusing on the hydrological and sediment-transport systems within the wetlands. The hydrological and sediment monitoring program is part of the overall Putrajaya lake management programme conducted by KLCC-UH and UM research and monitoring teams.

THE PUTRAJAYA LAKE & WETLANDS COMPLEX

The Putrajaya Lake & Wetlands Complex, at present, can be separated into two components of different and distinct water-bodies. It comprises the primary Putrajaya Lake (Lake 1A) and a complex of wetlands (Fig. 1). These two water-bodies have been artificially constructed and are closely linked; however they are different in their geographical or geomorphological locations and their hydrological functions.

I. The Wetlands component

The Wetlands component is a network of cellular and segmented water-bodies. The network comprises five wetland arms; these are the Upper West arm (UW), the Upper North arm (UN), the Upper East arm (UE), the Lower East arm (LE) and the Upper Bisa wetland arm (UB) (see Fig. 1). They are mainly located in the northern upstream region of Putrajaya (with the exception of UB, which is located in the south-east) and are directly connected at their upstream ends to the natural streams and rivers that flow into the Putrajaya district. These wetlands receive water and sediment mainly from the natural streams, rivers and the Wetlands drainage network. Slope incursions, especially near areas undergoing active construction work, are known to occur during periods of heavy rainfall (storm-water flows). The wetlands are designed to be multi-tributary, multi-cellular, water flow (stream) systems. These wetlands are meant to function as:

i. Surface-flow water harvesting system;
ii. Water retention and detention cells;
iii. Water filtering cells — with water plants to trap and reduce TSS content, to clean and filter the water supplied to the Lake;
iv. Water supply system — to ensure sufficient supply of water into the Primary Lake in order to maintain the lake at a healthy level.

Each wetland arm is segmented into small wetland cells along the downstream direction. Each cell is connected to another by a weir. The design of the cells and weirs is such that only water and suspended sediment is able to move from one cell to another in the downstream direction. The bed-load sediment is meant to be trapped in the cells; from the numerous sampling exercises that have been carried out, the sediment monitoring team have found that almost no bed-load entering at the upstream end moves beyond the first of the upstream cells (UW7, UN8, UE3, LE2 & UB2). The filtering-effect of the wetland cells also reduces the TSS (total suspended sediment) content of the flowing water as it moves through the cells downstream.

The wetlands are connected to Lake 1A at their downstream end by large overflow weirs at two locations, i.e. weir PL-08 (downstream CW) and PL1-15 (downstream UB). Only water and suspended sediment enters the lake through these weirs. No bed-load is introduced into Lake 1A via the wetlands.

II. Lake 1A component

Lake 1A is an open water-body complex designed to become the aesthetic centre of Putrajaya and is surrounded by city offices and residential areas. Like other open lake complex, Lake 1A is a recipient water-body of inputs of water and sediment from fluvial (and drains), colluvial (lake banks flows), organic matter, biogenic silica, lake bank erosion and rain and airborne dust. By design, two water-sediment delivery systems becomes the main transportation route of catchment-derived water and sediment into Lake 1A — the Wetlands system and the Putrajaya Drainage system.

The Wetlands water-sediment delivery system

Water and sediment from the wetlands enters Lake 1A via a large, overflow wier that link the wetlands system with the Lake. The weir is located at the downstream end of Central Wetland (CW) in the northern wetlands section. As noted earlier, only water and suspended sediment passes through the weir into Lake 1A.

The Putrajaya Drainage water-sediment delivery system

The drainage network of Putrajaya town and residential areas enters Lake 1A through at least 17 drain-mouths (see Fig. 1). Most of these drain-mouths have mini wetland cells or retention ponds (and GPT's) to filter the water and sediment entering Lake 1A.

This paper focuses only on the hydrological and sediment-transport systems within the wetlands.

OBJECTIVES AND MONITORING PROCEDURES

The specific objectives of the sediment monitoring programme are as follows:

i. to quantify the rate of sediment discharge (TSS — total suspended solid) at selected entry points of the lake and wetlands;
ii. to identify and chart the variability of sediment discharge rates in response to changes in weather conditions, particularly changes in the rainfall pattern;
iii. to evaluate the efficiency and identify the discrepancies of the wetland (i.e. the wetland cells) filtering capacity and competency; and
iv. to recommend the appropriate, preventive and remedial, measures to maintain and improve the efficiency of the wetlands and good water quality in the Lake 1A.

Samples and measurements were taken at stations that are located at the different overflow weirs connecting the different cells of the wetland arms. Three types of measurements/samples were collected at every sampling station. These are:

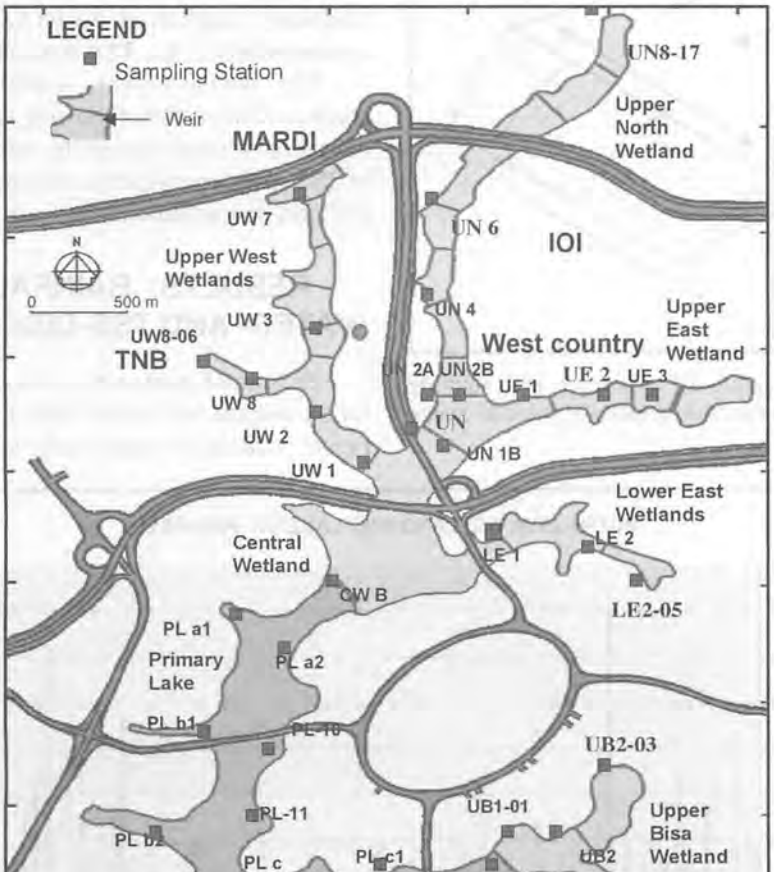

Figure 1. Map of Putrajaya Lake & Wetlands showing the wetland cells, Lake 1A, the selected sampling stations and other inlets.

i) Water flow/water discharge measurements

Two different methods were employed for the measurements of water flow and water discharge throughout the streams and weirs within the wetland cells and lake. These are the *Velocity-area method* and *Weir method.*

a) Velocity-area method

In this method, if the cross-sectional area (A) of a stream and the mean water velocity (V) are known, the discharge (Q) can be estimated using an equation, Q = V x A. The flowing-water velocity in the streams/entry points can be estimated using a current meter. The mean velocity in a vertical is obtained by measuring the velocity at specified depth in the vertical using a current meter. Due to the variable nature of gauging sites, a guideline in making velocity measurement for the rivers in Malaysia has been proposed by the Department of Drainage and Irrigation (DID, 1976, 1999).

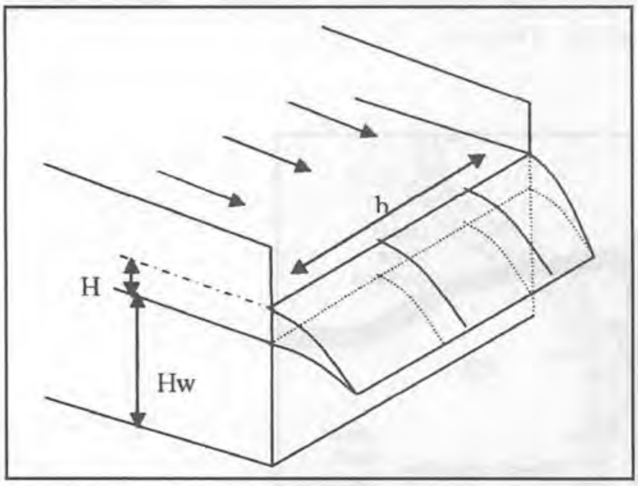

Figure 2. A simplified sharp-crested rectangular weir, showing the parameters measured for the measurements of water discharge (modified from Chin, 2000).

b) Weir method

In the Putrajaya wetland area, rectangular sharp–crested weirs have been constructed as the connecting drains between the wetland cells. With this weir type (Fig. 2), if the elevation of the backwater above the weir crest, H, can be measured, the discharge (Q) over the weir can be calculated from the following equation:

Q = 1.83bH3/2 Equation (1)

where

Q is the discharge (m^3/s)

b is the length of the weir crest (m)

H is the head of the backwater above the weir crest (m)

ii) Water samples (water-sediment mixture) for TSS (total suspended solid) concentration measurements

The TSS (total suspended solids), which refers to the quantity of sediments held in suspension in a stream, can be measured from representative samples of a water-sediment mixture. Although it is known that the TSS in any flow varies with space (and depth) and time, for the purpose of this monitoring exercise in Putrajaya, between one to two litres of water-sediment samples are collected at each sampling station, at water depth between 6–10 cm. A private laboratory, appointed by KLCC-UH, carried out the measurements of the TSS concentration.

The measurements enable the estimation & characterization of the following parameters: i) the volume of water discharge through the wetlands, and ii) the amount of TSS discharge which is the product of water discharge and TSS concentration.

RESULTS: RAINFALL PATTERN, WATER- AND TSS-DISCHARGE TRENDS

The rainfall pattern recorded at the Putrajaya Wetlands for the months of October 2001 to May 2002 is shown in Figure 3. Rainfall data is obtained from the sole rainfall-

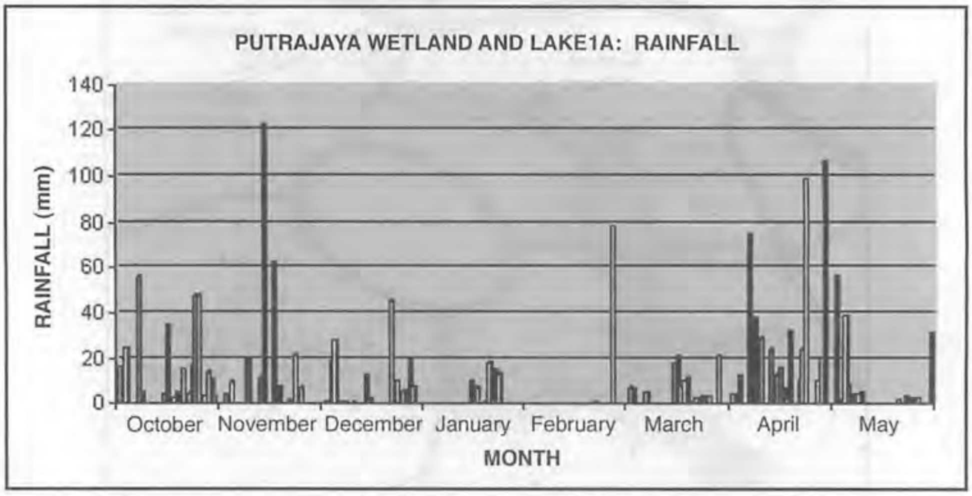

Figure 3. The rainfall pattern recorded at the Putrajaya Wetlands for the months of October 2001 to May 2002.

gauging station located at the KLCC-UH Wetland Site Office in Putrajaya Wetland Park. Two general, prominent modes can be recognised, one around the month of November 2001 and another around the months of April-May 2002.

Figures 4, 5, 6 and 7 shows the water discharge trends, TSS recorded at the UW, UN, UE and LE wetland arm respectively. The water discharge trends measured at all the wetland arms (Figs. 4a, 5a, 6a and 7a) clearly show good prominent peaks at around November 2001 and April-May 2002. These trends closely mimic the rainfall pattern. These results clearly indicate that water-discharges at the northern Putrajaya Wetlands are very much governed by rainfall.

Figures 4b, 5b, 6b and 7b shows the TSS concentration trends recorded at the different wetland arms. These graphs show similar peaks to those seen in the water-discharge graphs for the period October 2001 and April-May 2002. Thus, transportation of TSS within the wetlands complex is influenced by rainfall. However, the graphs also display other peaks during periods of low rainfall between November 2001 to April 2002. The latter peaks indicate that there are other factors involved in determining the volume of TSS entering the wetlands. These peaks are most prominent at the UW arm (Fig. 3b), but are also visible at the UN and UE arms.

Figures 4c, 5c, 6c and 7c show the TSS-discharge trends at the different wetlands. All the TSS-discharge trends closely resemble the water-discharge trends (and not the TSS-concentration trends). Water is the main medium that transports the TSS, downstream, along the wetlands. Thus, although the volume of TSS are high during months where rainfall is low, only a small volume will be transported downstream, due to the low water-discharge volume.

DISCUSSION

The close correlation of water-discharge trends with the rainfall pattern at the various wetland arms suggest that the rainfall data, despite being monitored at only one station, gives a good indicator of the overall rainfall trend within the northern Putrajaya district and the nearby catchment areas. The results also reflect the effectiveness of the water-harvesting function of the northern wetlands.

Erosion and transportation of earth's surface material by water are controlled by a variety of factors, most importantly include climate, relief, soil, vegetation and human activities (Jansson, 1982). The loss of soil from forested areas are normally minimal (Jusoff *et al.*, 1986). Soil movement and stream turbidity, related to rainfall, surface run-off and flooding is increased when land is cleared for construction purposes, thus exposing excessive amount of soil (Ang, 1986; Jusoff *et al.*, 1986). The removal of soil material becomes more rapid during intensive events such as storms. Intense tropical storms coupled with the availability of fresh sediment sources in upstream catchment areas will result in greater erosion and sediment yield, and sediment discharge in rivers (Trudgill, 1983; Wan Ruslan Ismail, 1996).

The northern upstream catchment areas of Putrajaya, shown in Figure 1, is where the TNB Perang Besar power station, MARDI Research Station, Universiti Putra Malaysia (UPM) and Universiti Tenaga Nasional (UNITEN) are located. The northwest sector (TNB & MARDI) is relatively more stable and less active in terms of construction and development activities. The north and north-eastern areas was undergoing active land clearing and construction works during the period of the study. The new Serdang-UPM Hospital and parts of UNITEN are some of the major structures under construction during the period. Thus, fresh sediment sources are continually exposed and made available for erosion and transportation. The high values of TSS recorded during periods of heavy rainfall and storm conditions are thus expected. The presence of natural streams and gullies, and man-made drainage networks help to increase the efficiency of sediment transport.

High TSS recorded during periods of low rainfall is not completely an anomalous trend. As noted earlier, rainfall readings were recorded at only one station. Pockets of heavy rainfall may have occurred during the period within the upstream catchment areas that is actively undergoing construction-development projects. The surface flow resulting from the moderate or heavy rainfall can transport TSS, which is readily available, downstream into the wetlands of Putrajaya. Man-made flushing, due to cleaning activities at construction sites, may also contribute to higher-than-expected TSS concentrations. However, this is expected to be small in volume. These results suggests that high TSS input from the upstream catchment areas into the Putrajaya Wetlands will continue until development activities in these areas stabilised.

CONCLUSION

1. Water-discharge within the northern Wetlands complex of Putrajaya (the UW, UN, UE and LE wetland arms) are directly controlled by rainfall. High discharges were recorded during the wet periods of November 2001 and April-May 2002.
2. The TSS concentration of samples from the wetlands record high concentrations during periods of high rainfall. These high TSS readings are the result of land clearing and construction activities in the northern upstream areas. However, TSS concentrations of the water-sediment samples also show notable peaks during low rainfall periods. This shows that the TSS concentration within the wetlands is only partially controlled by rainfall. Other factors, such as changes in land-use pattern, human activities and rainfall within the catchment areas may have contributed to the increase in TSS values.
3. Transportation of TSS within the wetlands is clearly governed by the rainfall. This is because water is the

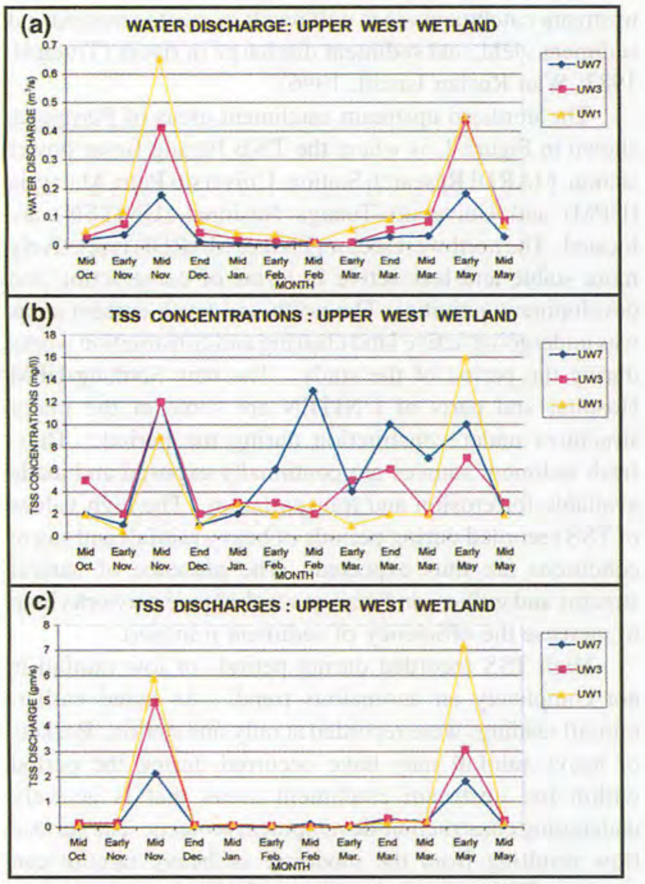

Figure 4. Plots of Water Discharge, TSS concentrations and TSS discharge trends recorded at Upper West arm, Putrajaya Wetland.

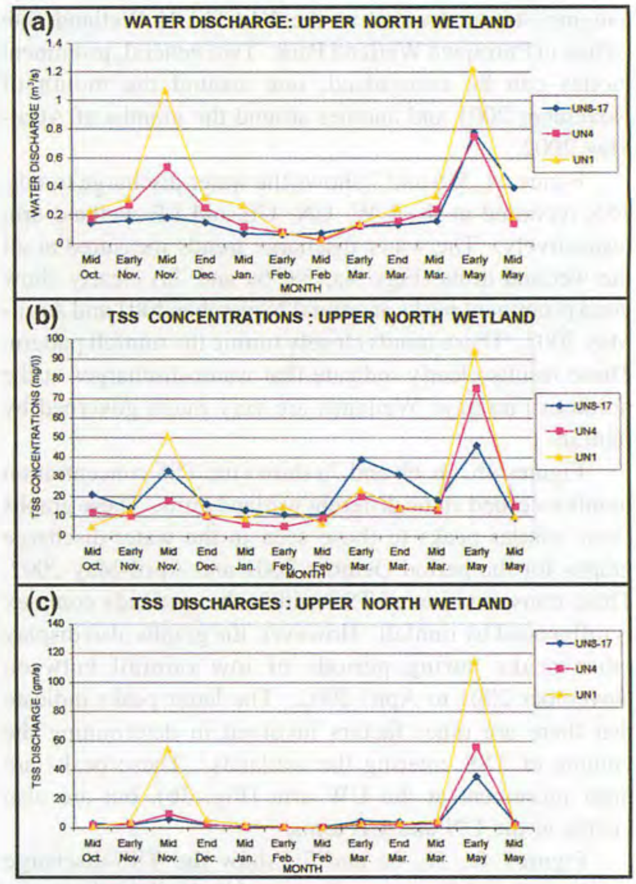

Figure 5. Plots of Water Discharge, TSS concentrations and TSS discharge trends recorded at Upper North arm, Putrajaya Wetland.

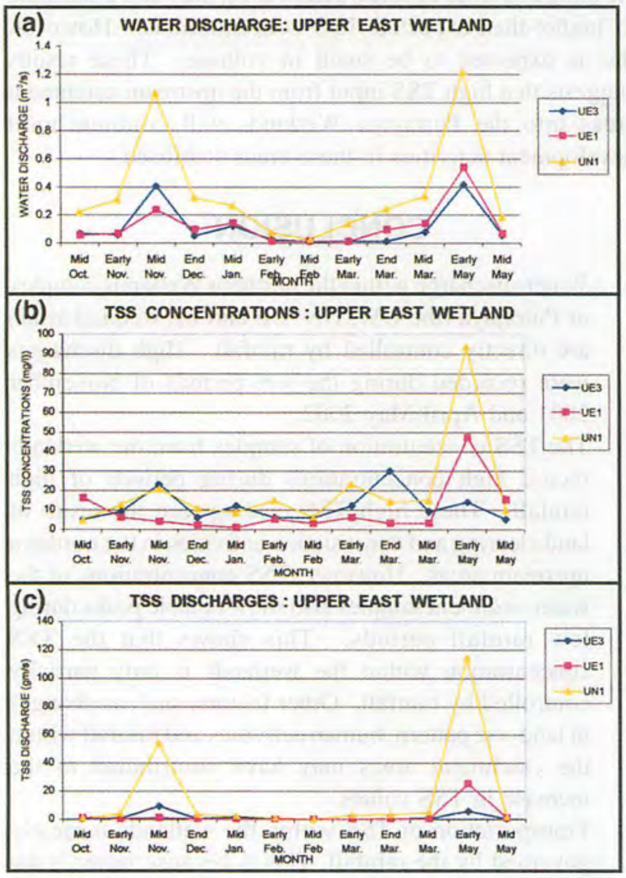

Figure 6. Plots of Water Discharge, TSS concentrations and TSS discharge trends recorded at Upper East arm, Putrajaya Wetland.

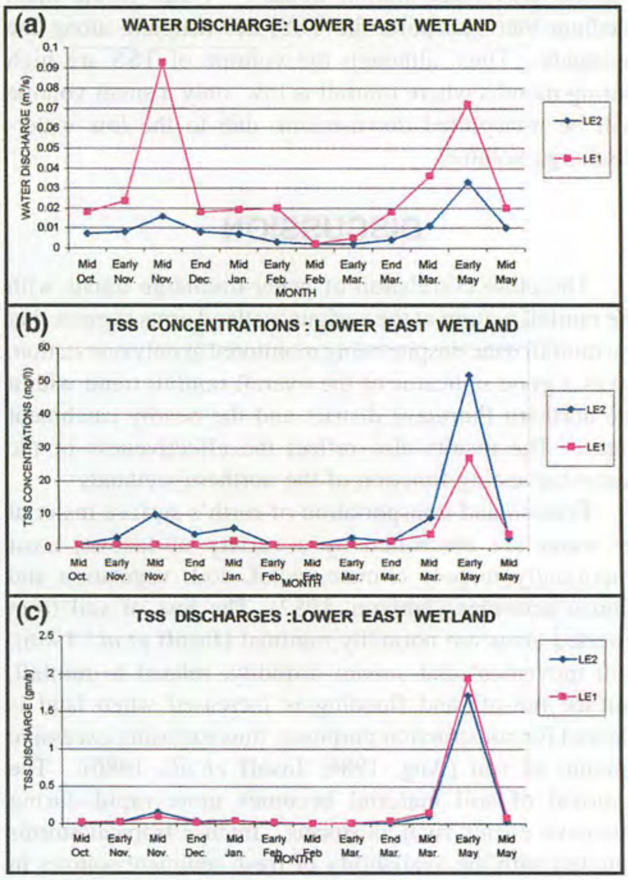

Figure 7. Plots of Water Discharge, TSS concentrations and TSS discharge trends recorded at Lower East arm, Putrajaya Wetland.

main medium that transports the TSS, downstream, along the wetlands.

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