DEVELOPMENT OF PUTRAJAYA WETLAND FOR STORMWATER POLLUTION CONTROL

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Abstract: The Putrajaya Wetland is developed with the primary objective of treating the catchment runoff before it drains into the Putrajaya Lake to ensure that the Lake's water quality meets the standard required for body contact recreation.

A multi-cell and multi-stage design was adopted for its advantage of better hydraulic performance and retention of pollutants, maximises areas for planting of macrophytes and facilitates accessibility for maintenance of the wetlands.

The constructed wetlands involve an area of 197 hectares and 12.3 million wetland plants is one of the largest constructed wetland in the tropics. It was completed in 17.5 months despite the lack of relevant data and experience in the design and construction of tropical wetland. Water quality monitoring carried out shows that the constructed wetland is effective in stormwater pollution control.

1. Introduction

Putrajaya is being developed as the new Federal Government Administrative Centre of Malaysia. It is located about 26 km south of Kuala Lumpur. A lake approximately 400 hectares is being developed as the centrepiece of the new city. The Putrajaya Wetland is designed primarily to treat the stormwater runoff before it discharges into the Putrajaya lake which drains a catchment area of 50.9km^2. Treatment of stormwater of such a scale using constructed wetlands has been rarely undertaken elsewhere.

The goals of the wetland project are as follows:-
To ensure the Putrajaya lake water quality meets the standard required for body contact recreation;

- To construct a wetland ecosystem which is unique to this part of the world;
- To develop a natural habitat for conservation of indigenous wetland flora and fauna;
- To promote public education and research on wetlands;
- To promote Putrajaya as an attractive destination for domestic and international tourism.

The project involves a total area of 197 hectares and 12.3 million wetland plants. It is one of the largest constructed wetland in the tropics. Construction of the wetlands started in March 1997 and was completed in August 1998.

2. Layout

The wetlands are strategically located to act as buffer for the Putrajaya lake. Figure 1 shows the general layout of the six wetland systems viz; Upper West, Upper North, Upper East, Lower East, Upper Bisa and Central Wetlands.

A series of rockfilled weirs (24 numbers) is constructed along the five arms of Sg. Chuau and Sg. Bisa which divide the area into 24 cells. The size and storage of each wetland system is shown below.

Wetland System	Upper West	Upper North	Upper East	Lower East	Upper Bisa	Central Wetland
Catchment Area (km^2)	5.53	11.54	3.34	1.73	4.03	24.7
Wetland Area (ha)	38.5	54.1	15.8	14.3	23.6	50.9
Normal Pool Area (ha)	27.0	38.3	10.8	9.5	20.6	48.3
Normal Pool Volume (ML)	230	310	130	150	430	1200

The wetlands are designed as multi-cells multi-stage units. The design has the advantage in achieving a better distribution of flows and maximises shallow areas require for planting of macrophytes. It also increases the accessibility for maintenance of wetlands. It provides a surcharge capacity above the normal pool level to extend the treatment capacity and reduces the hydraulic and pollutant overload during event flows.

A review by Wong etal (1996) of the current design practices for the use of wetlands for urban and agricultural runoff found them to be primarily based on wastewater treatment technology and are generally inadequate due to the inherent variability of stormwater runoff generation and pollutant loading.

3. Hydraulic Loading Rate

Design inflow rates for each of the wetland systems are estimated based on future condition after catchment development. In this exercise, thirteen years of daily rainfall records at Prang Besar rainfall gauging station from period 1981 to 1994 are used. Thirteen years of daily runoff data for each sub-catchments were generated using a rainfall runoff simulation model. The design inflow rates and hydraulic loading rates (HLR) for each wetland systems are shown in the table below.

Wetland System	Upper West	Upper North	Upper East	Lower East	Upper Bisa	Central Wetland
Design Inflow Rate (ML/d)	18.8	37.6	11.4	5.9	13.7	79.5
Mean Residence Time (d)	12.2	8.2	11.4	25.4	31.4	15.1
Hydraulic Loading Rate (cm/d)	7.3	11.1	8.9	6.2	6.7	15.1

Hydraulic loading rates directly influence the performance of wetland system although there is no simple correlation between this parameter with pollutant removal.

4. Pollutant Loading Rate

The Putrajaya catchment runoff contains moderately high concentration of phosphorus, nitrogen, BOD and some traces of heavy metals. Bacteriological contamination and total suspended solid are high in many samples analysed.

Projection of future pollutant loadings in Putrajaya have taken into account the final land use and population density. Given the policy of no heavy industry, total treatment of wastewater and the treatment of all point source pollutants, the values of total phosphorus in the order of 0.1 - 0.5 mgl^{-1} and total nitrogen values of 1.0-2.0 mgl^{-1} would be expected.

Phosphorus is a critical parameter as it is the most difficult chemical to retain in wetland systems and will results in eutrophication of the lake if excessive amounts are not successfully removed. The long term efficiency and sustainability of the wetland are governed by the phosphorus inputs over time, where excessive concentration can result in progressive saturation down each wetland resulting in decreasing efficiency of pollutant removal.

Based on the projected pollutant loading rates for future developed catchment condition, the future mean TP mass loading rates estimated range from 8.4 $gm^{-2}y^{-1}$ for Lower East Wetland to 15.0 $gm^{-2}y^{-1}$ for Upper North Wetland.

5. Wetland Pollutant Retention

The long term pollutant export and retention for the Putrajaya Wetlands and lake systems is simulated using the AQUALM model for thirteen (13) years of data (Angkasa GHD, 1996). Modelling was carried out to assist in the sizing of the wetlands and assess the eutrophication potential of the lake subject to the designed pollutant loading rates.

Owing to the highly variable nature of catchment runoff and associated pollutant concentration, a continuous simulation approach was undertaken in selecting the appropriate storage volume for each wetland on the basis of the long term overall performance rather than base on a prescribed performance for a single given event.

6. Design Configuration

Figure 2 shows a typical layout of wetland cell and plates 1-3 shows the wetland cells completed. A typical cell has the following components:-

- Inlet Zone - This is the immediate area where flow exiting from the outlet of the preceding wetland cell. Inflow into the cell is discharged through an outlet conduit into a plunge pool and spread over a rock bund to ensure even distribution of flow across the macrophytes zone.

- Sediment Forebays - Forebays are constructed at four locations to dissipate energy of inflows and settling of sediments. They are provided with access ramp for maintenance purposes.

- Macrophytes Zone - Beyond the inlet zone is the macrophytes zone consisting of three sub-zones with increasing water depth i.e, shallow marsh, marsh and deep marsh. The macrophytes zone is designed for growth of emergent wetland plants and is the primary nutrient uptake zone.

  The macrophytes zone is a relatively tranquil part of the wetland within which particle settling and adhesion to vegetation occurs. The density of macrophytes is about 10 crumps per square metre of area. The planting density is aimed at reducing flow velocities to prevent resuspension of sediment during high flows besides achieving the treatment capacity required.

- Open Water - The open water in each cell generally constitutes about 25% of the cell. The water here is exposed to sunlight for disinfection by ultraviolet radiation. The open water area allows settling of sediment, increase the scenic amenity and provides refuge for biota. The water is kept open by designing the pond sufficiently deep to prevent growth of macrophytes.

- Outlet Zone - The outlet zone consists of a weir, outlet structure with trash rack and a conduit embedded in the weir. The outlet structure allows the manipulation of water level in the cell. The ability to vary the water level in the cell is critical during plant establishment stage. The water level not only affect the hydrology and hydraulic of the system, but also has a great impact on the biota. The wetlands are designed with a set of operating water levels to provide the requisite residence time for the water to be treated.

- Intermittently flooded Zone - The fringes around the cell above the normal pool level are not the key treatment components of the wetlands. They are important for recreational landscape which link to adjacent developments.

7. Cell Morphology

Detailed shaping of the wetland cells is performed to achieve a wetland morphology conducive for plant establishment and hydraulic performance. Topography at the Putrajaya site is undulating and the cells have to be individually designed to accommodate the particular topography and drainage.

Design of cell morphology is an iterative process involving consideration of existing topography, water depth of the functional zones, surface area required and extend of earthwork needed in order to achieve the design desired.

Soil investigation carried out shows that residue soil of sedimentary rock with thickness of 3 to 8m covers the wetland area, which is sufficient to prevent excessive leakage in the cell. The topsoil with high organic content was stockpiled during excavation work and reuse for the planting zone. Extensive soil sampling and testing was carried out to ensure that the substrate is suitable for growing of macrophytes species selected.

8. Outlet Design

The outlet work is designed with a discharge capacity to enable the 1 year average reccurrence interval event flow to be retained in the flood attenuation storage for 3 days. It is designed to achieve about 80% of the catchment runoff to be retained for a period of 3 days. Somes and Wong (1196) had shown that outlet design has significant impact on the hydrologic effectiveness of a wetland system which is measured by the proportion of catchment runoff retained in a wetland for the prescribed minimum period. Also, the outlet configuration governs the distribution of water levels in the wetlands.

Froend etal (1993) has shown how plants distribute themselves over wetness gradients created by basin morphology and system hydrology. Wetland plants have evolved a range of adaptation to cope with growing in wet conditions (Hook 1984, Breem 1990).

9. Hydraulic Design

Hydraulic design is aimed at creating a well vegetated flow path with a high diversity of plant surfaces to enhance treatment of water by sedimentation, filtration and adsorption, while optimising retention time and minimising short-circuiting of flows.

The weirs are designed to control the flow velocity across the wetland cell of below 0.5 m/s during an event flow of 100 year return period in order to prevent uprooting of the macrophytes by floods. During the period of normal flows, the velocity through the wetland cells is kept below 0.1 m/s to enhance the treatment processes in the wetland.

The design water levels in the wetland cells generally vary from RL32m at the upstream cell to RL23.5 m in the downstream cell giving a cascading effect as the flows pass through the wetlands.

10. Vegetation Selection

The important role of macrophytes in stormwater pollutant control has been identified by many authors, example Culler (1990) found vegetation promotes performance of wetland systems by taking up nutrient directly, trapping sediment and supporting epiphytic growth. There is little information available on Tropical wetland plants and their nutrient removal efficiency. The type of plants, planting density, method of propagation, ect. of the plants selected for the Putrajaya wetland project are largely developed during the implement of the wetland project..

The use of native wetlands species is adopted to ensure sustainability of the botanical design of wetlands. A survey of the Selangor areas to study the habitats and understand the ecological requirements of wetland plants was carried out. The distribution of these plants involving some 70 species were mapped and their growth habits were studied. A total of 19 locations in Selangor, covering more than 100 sites were surveyed.

The selection for the plants took into consideration factors such as indigenous species, ease of propagation, availability, robustness, aesthetic value, ability to transfer oxygen to the roots and biodiversity.

11. Mosquito Control

Construction of the wetlands may lead to excessive breeding as in many unmanaged swamps in Malaysia. Stocking of larvivorous fish including pelaga (Beta pugnax) and Sepat Siam (Trichogester peotoralis) for controlling the breeding of mosquitoes.

12. Conclusions

- The Putrajaya Wetlands is designed for multi-functional use which include stormwater pollution control, creating a habitat suitable for conservation of native wetland floral and fauna, aesthetic amenity, community education and research on wetlands.

- The Putrajaya wetland is one of the largest constructed wetland in the Tropics . It involves an area of some 197 hectares and over 12.3 million wetland plant was completed in 17.5 months in a fast track programme.

- The multi-cell and multi-stage wetland design has the advantage of better hydraulic performance, maximises areas for plant growth, provides retention storage during food events and improve accessibility for maintenance of the wetlands.

- Achieving an optimal design of the Putrajaya wetland involves an iterative process in the design of the water levels in each wetland cells, water depths required for the various treatment zones, vegetation layout, cell morphology, hydrologic and hydraulic control.

13. References

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