
Adopting an integrated catchment-based management approach for Putrajaya Lake and Wetlands

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Abstract: The Federal Government of Malaysia's new administrative centre, Putrajaya, is being developed with a garden concept comprising an artificial lake and wetlands to balance the rapidly changing ecosystem and alleviate the impact of urbanisation on the former rubber and palm oil plantations. This newly transformed urban ecosystem will accommodate and enhance the city's estimated future population of 300,000 people. The urbanisation involving the development of residential, government office and commercial complexes, will inevitably have an impact on the surrounding environment. The development of Putrajaya Lake and wetlands over an area of 600 hectares will create a balanced biogenic environment and subsequently advocate the importance of urban eco-hydrological management systems within catchments. This paper reviews

the adoption of a new integrated catchments management approach through the example of Putrajaya in order to realise the desired level of ecosystem service and the water quality resulting from the environment.

Keywords: catchment management; constructed wetlands; eco-hydrology; ecosystem management; Putrajaya; recreational lake.

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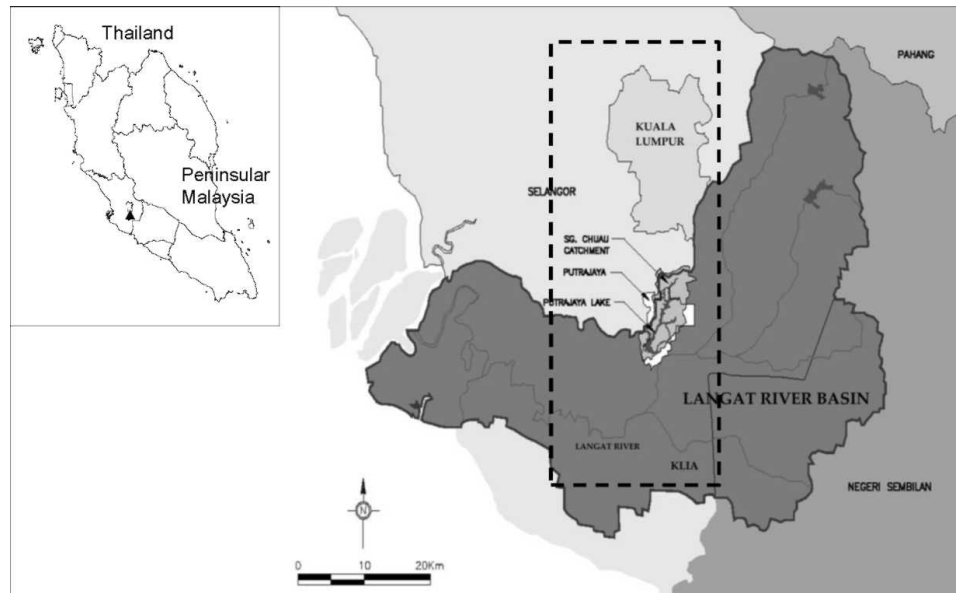
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1 Introduction

Putrajaya, the world's first intelligent garden city, is to be developed as the Malaysian Federal Government's Administrative Centre and has been designed according to sustainable development and management concepts. Located at the heart of the Multimedia Super Corridor (Figure 1), the development since 1990 of this new city has involved the opening up of a large tract of rubber and palm oil plantations, the former Prang Besar Estate, encompassing about 4,700 hectares, into a new urban city. The designed master plan of Putrajaya includes the development of government and commercial complexes and peripheral residential areas that integrate riparian and botanical parks, water courses, wetlands and open spaces for reinforcing a 'City-in-a-Garden' impression. The notion of the particular urban configuration for Putrajaya is to realise the connection between living beings and ecosystems.

Figure 1 The Putrajaya Lake and Wetland Catchments within the larger Sungai Langat River Basin



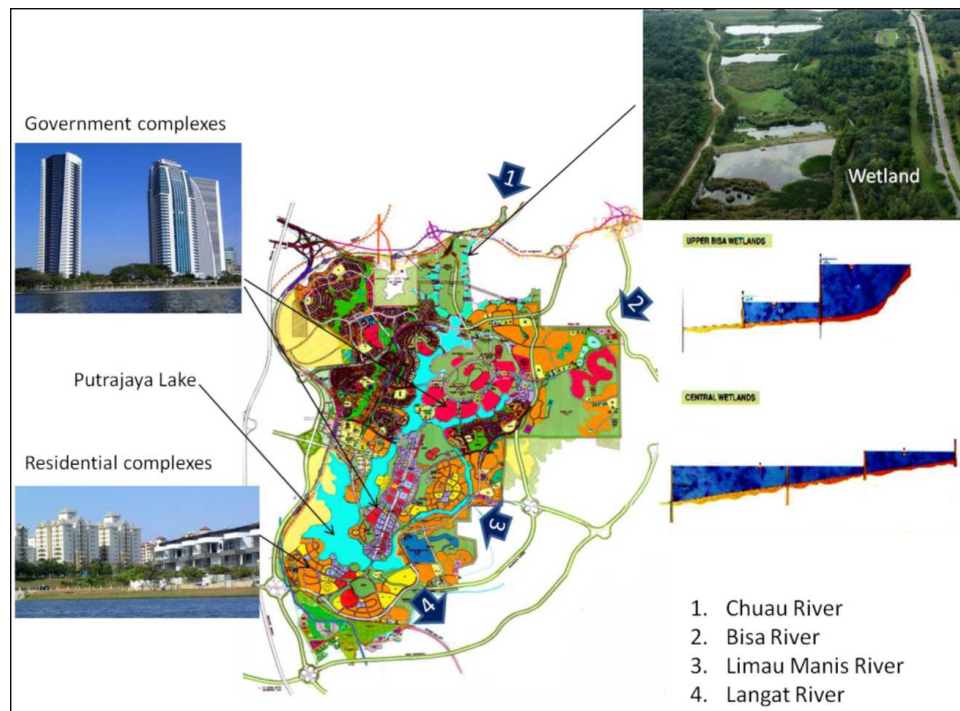
Note: Triangle indicates the location of Putrajaya within the Peninsular Malaysia.

The transformation of this new city has involved the removal of the rubber and oil palm trees that alter hydrological processes and enhance surface runoff, which can create flooding in downstream areas, as well as pollution resulting from soil erosion. Additionally, the clearing activities are likely to result in an increase in temperature in the new urban areas, induced by the exposure of cleared land to daytime heat in the early years of development prior to the full re-vegetation. In view of the future environmental impacts on its surroundings, Putrajaya has adopted innovative urban ecological management that combines an eco-hydrological approach and integrated catchment management concepts. This comprehensive urban ecological management includes the

creation of a large artificial water body in the form of a wetland and lake to enhance the city's environment. This study aims to:

- 1 review the adoption of the catchment development approach
- 2 describe the development components needed for sustaining Putrajaya and realising its vision.

Figure 2 Putrajaya Masterplan connecting urban city complexes with artificial water body and green parks and wetlands (see online version for colours)



Source: Modified from Perbadanan Putrajaya (2000)

2 The city of Putrajaya and its designed concept

Putrajaya, located in the Langat River Basin, has a relatively flat topography that is surrounded by steep-sided hills. The major rivers are the Chuau, Bisa and Limau Manis, which flow southward to the Langat River (Figure 2). The design goal in the planning of Putrajaya includes the creation of a functional city that serves both biogenic and the sociogenic functions. A central feature of the city's development is Putrajaya Lake, which has been designed for establishment at the core of the city. To achieve a high standard of lake water quality, the designed master plan proposed the construction of multi-tiered wetlands for clearing away catchment runoff before it enters the lake. The sociogenic function of the city is achieved through the creation of a sustainable environment that supports recreational activities such as kayaking, cruising, wind-surfing, bird watching, jogging and cycling. Additionally, the lake was designed as a venue for

national and international water-sport events such as rowing and fishing competitions, in addition to functioning as a unique irrigation and flood mitigation system.

3 Catchment development approach for sustainable Lake Basin management

The management of Lake Basin drainage has been promoted as a vital element for the successful management of lakes with regard to degradation of the lake environment (ILEC, 2005). Studies in the late '90s of over 28 water bodies worldwide indicated that 79% of the lakes studied were facing threats emanating from their basins, including effluent and stormwater discharges, non-point sources and excess sediment input (ILEC, 2005). These problems are largely found in lakes that are located in developing countries and might stem from excessive urbanisation (ILEC, 2005). As the transformation of creating a new urban city from rural agricultural land can induce similar problems, various hydrological and ecological technologies are being adopted as part of catchment development in Putrajaya to control pollution originating from the basin.

3.1 Ecosystem management

3.1.1 Constructed urban water body and wetlands

About 650 hectares (14%) of Putrajaya land use was designed for the formation of wetlands, a green riparian zone and a lake system (Perbadanan Putrajaya, 2000). The purpose of the water course was, among others, to create or shape wind movement within the constructed forms, thereby enabling the cleansing of air and eliminating the urban heat island effects. Cities located near natural waterways, such as along the sea, were reported to have special characteristics not present in cities without significant bodies of water (Lang, 1994). The Putrajaya Lake, spreading over an area of 400 hectares, is relatively shallow; water depth ranges from 3 to 14 m, with an average depth of 6.6 m (Salamat, 2007). Green buffer strips or riparian zones of 10 to 30 m in width were created on both sides of the lake to separate the water bodies from the development areas (Majizat et al., 2010). Additionally, the lake is connected to wetland cells in the upstream, which comprises six arms with a total area of about 200 ha and controls the transmission of pollutants directly into waterways within the city and downstream (Majizat et al., 2010). The wetlands concept was created to treat surface runoff by utilising a retention pond and aquatic plants as filters. Designed as multi-cells, multi-stage units that imitate an actual wetland ecosystem, the wetlands aim to provide an improved distribution of water flows for effective pollutant uptake capacity by macrophytes and cost-effective wetland maintenance (Khor, 1998; Shutes, 2001). About 56% of the runoff from the entire catchment in the north flows downward into the wetland cells before entering the lake, while the remaining 44% floods directly into the lake. In addition, a piping connection was established between the lake and wetland system to enhance the water cycle, re-circulating the lake water to wetland cells to maintain the wetland's water level during drought and extreme low flow to sustain the ecosystem function. The creation of a green belt around the lake, as well as the city

incorporating the blue-green network concept, which has been successfully applied in Lodz (Poland) all contribute to creating a more resilient city (Zalewski et al., 2012; Wagner and Breil, 2013).

3.1.2 Pollutant control

Pollutant control is an essential element for the success of water-quality enhancement in the Putrajaya Wetlands. Since the creation of the wetlands was considered as polishing mechanism, minimisation of pollutant generation at source is a major focus in pollutant control. Sewage effluent discharges have been identified as a major source of pollution in Malaysia (DOE, 2011). To control sewage discharges, centralised sewage treatment systems were built, with a design discharged of a total phosphorus load of 2 µg/l, to collect and treat sewage flows prior to discharge outside the Putrajaya catchment (Perbadanan Putrajaya, 2000; Salamat and Sahat, 2004). Sewage flows from future development areas within the lake catchment will be diverted outside the catchment (Salamat and Sahat, 2004). Additionally, laboratory wastes are not permitted to be drained into the drainage system that flows into Putrajaya (Perbadanan Putrajaya, 2000). In order to reduce pollution derived from eroded soils and sediment, land development activities were controlled: land earthwork clearing was only allowed over an area of less than 15% of the catchment at one time (Perbadanan Putrajaya, 2000). A new 'Erosion and Sediment Control By-Law' and a Standard Manual were introduced to stipulate the specifications and design standards for erosion and sediment control (Perbadanan Putrajaya, 2000). Best-practice management guidelines on the use of fertilisers and pesticides were established and adopted to control and monitor application of fertilisers and pesticides within the catchment.

3.2 Hydrological alteration and management

Urbanisation usually results in vegetation-covered soil being changed into waterproof areas, which reduces the penetration of water into the ground and subsequently has a hydrological impact, such as altering the water cycle. The expansion of urban and paved areas reduces water infiltration and evapotranspiration (Zalewski et al., 2012) and increases surface run-off, while also changing peak flow characteristics and river discharges; additionally, flooding problems may occur (Leopold, 1968). Flood discharges can increase by as much as 50% in areas with highly pervious surfaces and this percentage increases up to 400% in cities with 80% impervious surfaces and that are storm-sewered (Chandler, 1976). In order to reduce the hydrological impacts associated with an increase in runoff volume and velocity, as well as the pollutants resulting from the extensive development in the Putrajaya area on downstream areas (specifically the Lower Langat River Basin), the Putrajaya Lake and Wetland (PLW) project has adopted an integrated management and engineering approach for addressing these problems. A comprehensive PLW Management Plan was developed, as shown in Table 1.

3.2.1 Drainage control

The Putrajaya Drainage Master Plan (PDM) aims to mitigate surface runoff and pollutant exports to downstream areas and protect the public from flooding (Perbadanan Putrajaya, 2000). It plans to preserve urban ecological values within the PLW in addition to

providing a cost effective and maintainable drainage system. The PDM, which was based on vegetated landscape drainage corridors, has embraced both hydraulics loading rates (HLR) and pollutant loading rates in its design calculations and hydrological models. The vegetated corridors function to absorb increasing fluxes of water from other impermeable areas subsequently reduces fluvial flooding. The adoption of a water quality model using pollutant retention curves (based on hydraulic residence time) for the estimation of a daily pollutant removal rate is a significant improvement from the conventional drainage designs that only incorporates HLR. By assuming total phosphorus as the limiting nutrient, eutrophication potential was assessed using the Vollenweider method and subsequently enabled management of pollutants based on the carrying capacity of the water body.

Table 1 Putrajaya Wetland and Lake Management Plan

<i>No.</i>	<i>Guideline</i>	<i>Year introduced</i>	<i>Function</i>
1	Putrajaya Drainage Master Plan	1998	To provide overall planning of the drainage system
2	Putrajaya Urban Design Guidelines (UDG)	August 1998	To provide the planning and development guidelines for the development of different precincts in Putrajaya
3	Putrajaya Stormwater Management Design Guidelines	Jun 2000	To ensure the implementation of the drainage concepts and systems defined in the UDG in the engineering design
4	Putrajaya Lake Catchment Development and Management Guidelines	1998	To provide a set of guidelines and plan for managing Putrajaya Lake
5	Putrajaya Lake Management Guidelines	1998	To set the ambient water quality standards
6	Putrajaya Lake Use and Navigation Master Plan	August 2001	To provide an overall plan for the use of the lake
7	Putrajaya Environmental Management Guidelines	1998	To define environmental policy and strategy including environmental legislation, guidelines and requirements to be complied with in project developments
8	Putrajaya Irrigation Master Plan	1998	To provide a landscape irrigation plan throughout Putrajaya

Source: Perbadanan Putrajaya (2000)

3.2.2 Stormwater management

The Putrajaya Stormwater Management Design Guidelines (PSMDG) were introduced with the aim of effecting stormwater drainage, the management of stormwater as a resource, and the protection of both the receiving water quality and downstream ecological health (Perbadanan Putrajaya, 2000). The PSMDG address the need for managing pollutant loading and to control the associated changes in runoff hydraulics such as the volume, speed and flow rate of water. The PSMDG outline various design

considerations for meeting specific stormwater management objectives for the city, such as:

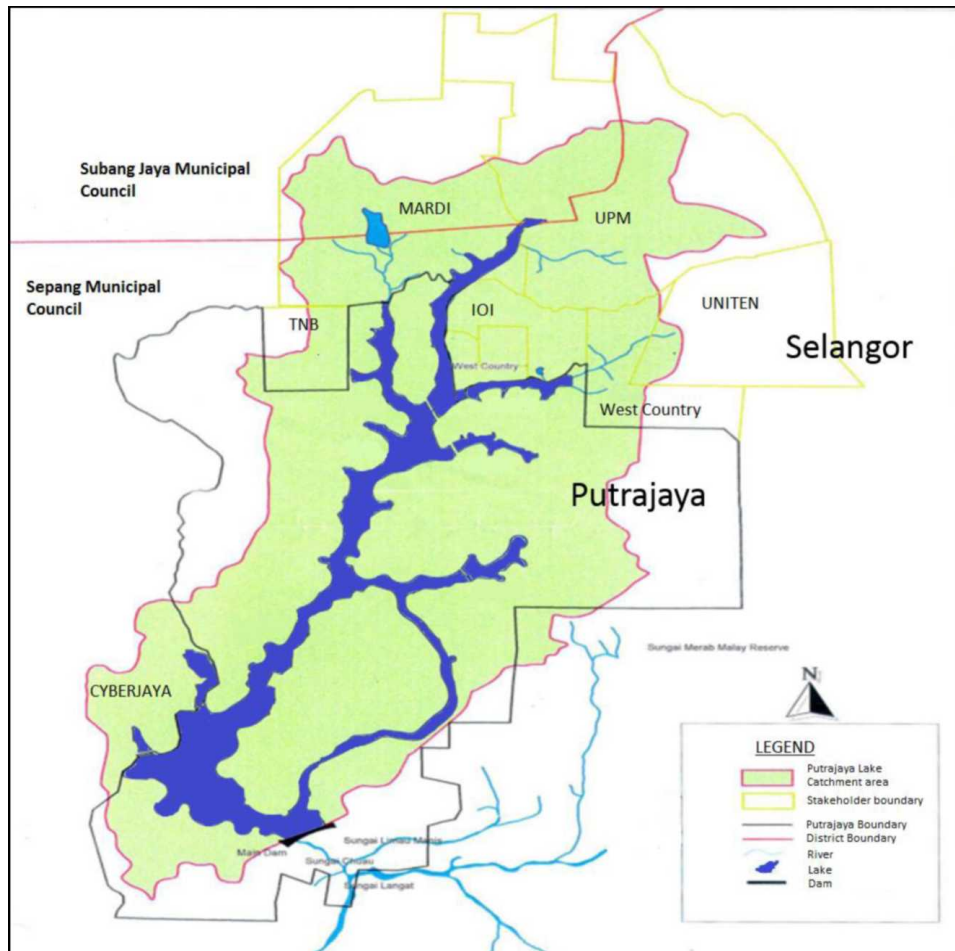
- 1 structural measures to prevent urban litter and its disposal in the stormwater drainage system
- 2 introduction of flow detention and an in-stream impediment to prevent excessive disruption of the lake ecosystem by stormwater runoff for the protection of downstream aquatic habitats
- 3 land use planning and regulation as the control mechanism for pollutants at source and for the establishment of gross pollutant traps in the drainage transit area (Perbadanan Putrajaya, 2000).

3.2.3 Watershed management and control

Integrated Lake Catchment Development and Management Guidelines were introduced within the catchment area of the PLW to control the urbanisation impacts on the river downstream, the Langat River system. Additionally, catchment-based management mechanisms were formulated for monitoring and controlling the discharge of pollutant loading in the upstream region to comply with the designed level's aim of enhancing wetland efficiency by stripping the phosphorus loading in the Putrajaya Wetland. This includes the development of primary sedimentation basins to control upstream discharges before they can enter into the wetlands, as well as hydropeaking the system. The management design, which enhances the inter-relations between hydrological processes and biota, are akin to the eco-hydrological approach introduced by Zalewski et al. (1997) and Zalewski (2002), which recognises the functional two-way interaction between hydrology and ecology at the catchment scale. Putrajaya has been acknowledged as one of seven sites in the UNESCO IHP Operational Site programme for its eco-hydrological approach in 2009.

As the pollutants transported into the Putrajaya Lake system will incessantly be derived from the surrounding catchment basin, either from within its boundaries or from the catchment's basin, which lies outside its periphery and jurisdiction, the establishment of a single authority was essential for driving not only the development, but also the administration of activities in the catchment. However, Putrajaya Lake catchment lies within two states and is administered by three different municipalities, namely the Majlis Perbandaran Sepang, Majlis Perbandaran Subang Jaya and Perbadanan Putrajaya. About 30% of the catchment areas outside the Perbadanan Putrajaya jurisdiction are owned by different stakeholders including Universiti Putra Malaysia (UPM), Malaysian Agricultural Research Development Institute (MARDI), Industrial Oxygen Incorporated Bhd (IOI), Universiti Tenaga Nasional (UNITEN) and Cyberjaya, which are in turn controlled under the authority of Majlis Daerah Sepang and Majlis Perbandaran Subang Jaya (Figure 3). To ensure sustainable lake quality management, the management approach of the lake system needs to be extended to the management of the overall catchment basin. This includes addressing the response and interactions between the PLW and the surrounding catchments through a comprehensive legislative framework for catchment management.

Figure 3 Putrajaya Lake Catchment area encompassing the Federal Territory of Putrajaya and the state of Selangor (see online version for colours)



3.3 Statutory control

Regulatory controls are crucial for underpinning technical intervention in Lake Basin management. Various regulatory controls have been introduced in lakes worldwide to enhance lake management (ILEC, 2005). Despite various legislations having been in place and enforced by respective government agencies in the country to control pollution and drainage on land and in rivers, comprehensive statutory frameworks for the integrated management of any particular catchments of such water bodies in Malaysia does not yet exist. In order to provide Putrajaya with effective control over maintaining the Putrajaya lake quality to its designed and acceptable condition, new legislation was introduced for controlling development around the lake.

3.3.1 *Legislation strengthening*

In addition to protecting the lake from surface water pollution, it is Putrajaya's policy that the PLW has to be an integral and interactive part of the community. Activities such as fishing, boating, swimming and eco-tourism, as well as the construction of floating structures such as restaurants on and along the water front, are all allowed on the lake, with certain controls having been put in place for monitoring these activities. Thus, sufficient legal powers to control any activities that may have an adverse impact on the lake have been formulated and are strictly enforced as part of effective lake use management. The legislation ensures that the objectives in the Putrajaya Master Plan can be achieved in a systematic and regulated manner; at the same time, this enables the Putrajaya Corporation (hereafter 'the Corporation') as a local authority to have effective control over the lake for maintaining it in an acceptable condition. The legislation is also crucial in complementing the implementation of other guidelines.

In contrast to developed countries such as the USA, where laws pertaining to lakes are in place in various states, specific laws relating to the control of a lake per se do not exist in Malaysia. Thus, a new set of laws were introduced under the purview of Act 536 of the Perbadanan Putrajaya Act 1995 and Act 171 of the Local Government Act 1976, which allow for the making of by-laws to control most if not all activities on the lake. Act 171 not only authorises the Corporation to create by-laws for controlling and governing the lake and city area, but also provides the Corporation with the authority to establish and manage places like public recreational parks or botanical gardens, as well as the lake itself.

The enactment of the Control of Activities on the Lake (Federal Territory of Putrajaya, 2004) By-Laws 2004, which came into force on 21 October 2004 (hereafter 'the By-Laws') provide:

- 1 additional measures in the controlling or prohibiting of certain acts or activities in the lake area: such as zoning and control over the use, flow and diversion of water
- 2 enforcement power including the power to arrest, search, seize and remove boats and water craft that commit unlawful activities on the lake.

The Federal Territory of Putrajaya (Licensing and Registration of Activities on the Lake) Regulations (2004) were enacted concurrently with the By-Laws to administer the registration and licensing of boats and the issuance of permits for water-based activities, and apply to any water craft carrying passengers or cargo, or performing any works on or in the lake.

Additionally, the legislation also provides for the control of all activities that are to be undertaken in the lake and wetlands, and is supplemented by several user guidelines such as the Guidelines for Licensing of Motorized Leisure Boats, the Guidelines for Licensing of Fishing, the Code of Practice for Boating and guidelines for activities requiring permits and approval in order to assist users in carrying out activities within the confines of the law. In the Federal Territory of Putrajaya Act 1995, the Corporation has the power of a local authority and is subsequently empowered to enforce primary municipal laws, among them the Local Government Act 1976, Street, Drainage and Building Act 1974 and the Town and Country Planning Act 1974, as well as environmental regulations under the Environmental Quality Act 1974.

Table 2 Comparison of Putrajaya Ambient Lake Water Quality Standards (PLWQS) and National Water Quality Standards (NWQS)

<i>No.</i>	<i>Parameter</i>	<i>Unit</i>	<i>PLWQS</i>	<i>NWQS (Class IIB)</i>
<i>Chemical</i>				
1	Dissolved oxygen	mg/l	5–7	5–7
2	pH	-	6.5–9.0	6–9
3	Temperature	°C	Normal ± 2	-
4	Transparency	m	0.6	-
5	Chlorophyll-a	$\mu\text{g/l}$	0.7	-
6	Total phosphorus	mg/l	0.05	0.2
7	Nitrate	mg/l	7	7
8	Nitrite	mg/l	0.04	0.4
9	Ammoniacal nitrogen	mg/l	0.3	0.3
10	Ammonia	mg/l	0.02–0.03	-
11	BOD	mg/l	3	3
12	COD	mg/l	25	25
13	Turbidity	NTU	50	50
14	Total suspended solids	mg/l	50	50
15	Colour	TCU	150	150
16	Conductivity	$\mu\text{S/cm}$	1,000	1,000
17	Salinity	ppt	1	1
18	Hardness	mg/l	250	250
19	Oil and grease	mg/l	1.5	-
20	Iron	mg/l	1	1
21	Manganese	mg/l	0.1	0.1
22	Zinc	mg/l	5	5
23	Lead	mg/l	0.05	0.05
24	Mercury	mg/l	0.0001	0.001
25	Arsenic	mg/l	0.05	0.05
26	Nickel	mg/l	0.02	0.05
27	Copper	mg/l	0.02	0.02
28	Cadmium	mg/l	0.002	0.01
29	Total chromium	mg/l	0.05	0.05
30	Boron	mg/l	1	1
31	Barium	mg/l	1	1
32	Silica	mg/l	50	50
33	Sulphur	mg/l	0.05	0.05
34	Sulphate	mg/l	250	250
35	Silver	mg/l	0.05	0.05
36	Antimony	mg/l	0.03	-
37	Beryllium	mg/l	0.004	-
38	Cyanide	mg/l	0.02	0.02
39	Selenium	mg/l	0.01	0.01

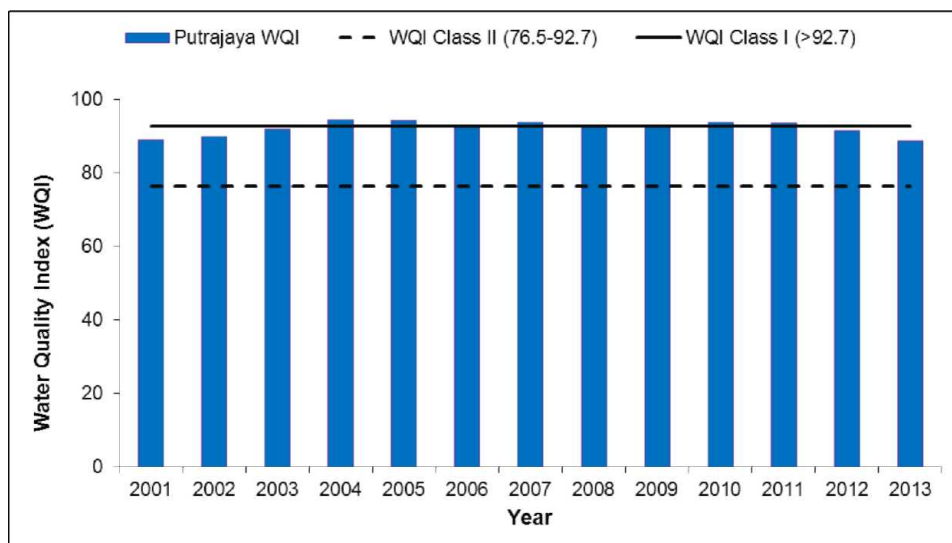
Table 2 Comparison of Putrajaya Ambient Lake Water Quality Standards (PLWQS) and National Water Quality Standards (NWQS) (continued)

<i>No.</i>	<i>Parameter</i>	<i>Unit</i>	<i>PLWQS</i>	<i>NWQS (Class IIB)</i>
40	Aluminium	mg/l	< 0.05 if pH < 6.5 < 0.1 if pH > 6.5	-
41	Fluorine	mg/l	1.5	1.5
42	Free Chlorine	mg/l	1.5	-
43	Taste		No objectionable taste	No objectionable taste
44	Odour		No objectionable odour	No objectionable odour
45	Floatables		No visible floatables (NF)	No visible floatables
<i>Microbial constituents</i>				
46	Faecal coliforms	counts/100ml	100	400
47	Total coliforms	counts/100ml	5,000	5,000
48	Salmonella	counts/l	0	-
49	Enteroviruses	PFU/L	0	-
<i>Radioactivity</i>				
50	Gross-alpha	Bq/l	0.1	0.1
51	Gross-beta	Bq/l	1	1
52	Radium-226	Bq/l	< 0.1	< 0.1
53	Strontium-90	Bq/l	< 1	< 1
<i>Organics</i>				
54	Carbon chloroform extract	µg/l	500	500
55	MBAS/BAS	µg/l	500	500
56	Oil and grease (mineral)	µg/l	40; NF	40; NF
57	Oil and grease (emulsified edible)	µg/l	7,000; NF	7,000; NF
58	PCB	µg/l	0.1	0.1
59	Phenol	µg/l	10	10
60	Aldrin/Dieldrin	µg/l	0.02	0.02
61	BHC	µg/l	2	2
62	Chlordane	µg/l	0.08	0.08
63	t-DDT	µg/l	0.1	0.1
64	Endosulfan	µg/l	10	10
65	Heptachlor/Epoxide	µg/l	0.05	0.05
66	Lindane	µg/l	2	2
67	2,4-D	µg/l	70	70
68	2,4,5-T	µg/l	10	10
69	2,4,5-TP	µg/l	4	4
70	Paraquat	µg/l	10	10

3.3.2 Environmental monitoring

In order to ensure management success, stringent Putrajaya lake water quality standards (PLWQS) have been enforced for water contact activities in Putrajaya Lake. The Putrajaya Lake Management Guide sets the ambient water quality in the lake to a standard that is slightly higher than the National Standard Class IIB for recreational purposes set by the Malaysian Department of Environment. A total of 45 physicochemical parameters, four microbiological constituents, four radioactive constituents and 17 organic parameters were monitored. A comparison of the PLWQS parameters with the NWQS (DOE, 2011) is provided in Table 2. Transparency measured by Secchi disk depth, chlorophyll-a and total phosphorus were parameters assessed by the Carlson Trophic State Index (TSI) and were also monitored. Water quality was assessed based on the Department of Environment Water Quality Index (DOE, 2011) and Carlson's TSI (Carlson, 1977). The aim of Putrajaya Lake management is to produce an oligotrophic to Mesotrophic Lake for delivering its multi-functional uses (Salamat, 2007). The trophic status of Putrajaya Lake is an indication of its biological condition and has therefore become an important measurement criterion for the success of its management.

Figure 4 Putrajaya Lake water quality based on water quality index (2001–2013) (see online version for colours)



The water quality monitoring programme has been conducted since 2000 in order to achieve environmental management efficiency and ensure the suitability of the lake for recreational purposes. The average annual Putrajaya Lake Water Quality Index over the period 2001 to 2012 indicated that the lake is always well above the Class II limits and in certain years (2004, 2005, 2007, 2010 and 2011) even breached the Class I limit (Figure 4). This high water quality indicates that the environment is being effectively managed. The trophic assessment based on chlorophyll-a over the period 2004 to 2012 was in the mesotrophic category, indicating more moderate biological productivity. Additionally, since the PLW has been operational, the biological monitoring of plankton, fish and benthic communities have shown a significant increase in biodiversity within the

newly developed urban environment. Both phytoplankton and zooplankton diversity in the lake has increased from nil to more than 105 and 54 species, respectively, in 2012 (unpublished data). The availability of diverse plankton communities could provide food for the expansion of larger fauna communities such as fish, amphibia and birds. Corporation records show that fish and bird species have amplified from 10 and 35 species, respectively, in 1995 to 18 and 124 species in 2012. Putrajaya Lake and its surroundings were important sites for migratory birds such as *Egretta eulophotes* (Chinese egret), *Pluvialis fulva* (Pacific golden plover) and *Gallinula chloropus* (water cock), the growth of which has been closely linked to the heterogeneity of aquatic vegetation, prey distribution and foraging success in the newly established PLW system (Ismail et al., 2010; Rajpar and Zakaria, 2013).

4 Challenges and the way forward

The catchment development approaches as underlined above are, however, restricted to the Federal Territory of Putrajaya. Subsequently, the legislation being managed for effectively controlling the water quality of Putrajaya Lake has no extraterritorial effect. Thus, activities at the upper lake catchment outside Putrajaya and within the municipality of Subang Jaya and Sepang in the state of Selangor remain a threat to the lake's ecosystem. A small number of studies have illustrated that the water derived from upstream sources and outside of the Putrajaya development boundary carried elevated levels of pollutants (Daud et al., 2011). Incidences of algae blooms have been reported in the wetlands (Majizat et al., 2010). Activities and future development in the upper 30% of the Putrajaya Lake catchment area are expected to increase run-off and pollutant concentrations flowing into Putrajaya Lake, which poses a threat to the water quality. As such, it is vital to create feasible mechanisms that will allow for strategic intervention to mitigate any negative impacts on Putrajaya Lake, thereby ensuring successful catchment protection and conservation.

Several legislative arrangements have been proposed to the State Government of Selangor to enhance the lake catchment management:

- 1 Re-delineate the Putrajaya Lake catchment boundary to encompass areas in Putrajaya and the state of Selangor.
- 2 Draw up a comprehensive Special Area Plan (SAP) combining the Putrajaya Lake catchment areas with the Sepang and Subang Jaya local authorities' areas, and include monitoring requirements, regulatory controls and mitigation measures.
- 3 Identify a protected area akin to the SAP area under Section 48 of the Selangor Water Management Board (LUAS) Enactment 1999 as an alternative measure for ensuring that the water quality and volume in the Putrajaya Lake is not affected by the development activities within the state of Selangor.
- 4 Consider instituting under Section 56 of the LUAS Enactment 1999 additional regulatory controls for development activities and their impacts within a larger catchment area.

To support these legislative arrangements, strong institutional arrangements have been proposed to facilitate the implementation and enforcement of the conditions under SAP.

A joint management committee comprising the Putrajaya Lake institutional stakeholders in both Selangor and Putrajaya plays a crucial role in coordinating the implementation of the recommended measures by all stakeholders to monitor and manage activities in the catchment area for the conservation and protection of Putrajaya Lake's water quality. An ideal institutional arrangement would be the establishment of a joint management authority that can regulate the implementation of the legislative provisions of each party. The Langat Basin Action Committee is currently the platform that fulfils the roles of joint management committee and joint action committee.

5 Conclusions

The integrated lake catchment management approach adopted by Putrajaya is Malaysia's first development project concerning an integrated water management system. Multiple eco-hydrological approaches that combine bio-remediation technology with policies and regulations have been employed since the lake's creation, and have effectively controlled trans-boundary activities outside Putrajaya and enabled the lake quality to remain at its highest, thereby providing important ecosystem services, i.e., the lake having recreational and navigational purposes. Despite challenges, the integrated eco-hydrological approach seeks to establish Putrajaya Lake as a reference case and a model for other lakes and water bodies worldwide.

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