CHAPTER 3

MATERIALS AND METHODS

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3.1 Study Sites and Data

Bera Lake is located at $2^{o}47$-$3^{o}9$'N-$102^{o}47$'E, in south-eastern part of Temerloh, State of Pahang, Malaysia. Bera Lake drains northwards through a single river, the Sungai Bera, tributary of Sungai Pahang.

Its catchment area covers approximately 6,150 ha of wetland in a watershed of 61,383 ha. Bera Lake has a dendritic drainage pattern and an extensive sinuous arm of water which is moving at varying speeds with maximum flow occurs at the limnetic area. Figure 3.1 shows the dendritic drainage pattern of Bera Lake and the extent of mire area (in gray shades) and the peat swamp tributary.

75% of the swamp area is occupied with vegetation consisting of three major habitats. (1) Swamp forest stands, constitute about two-third of the littoral area and dominated by *Eugenia*. (2) Remaining littoral comprises of reed (*Lepironia*) and *Pandanus* tree. (3) 1% of open water or limnetic area which is fringed by stands of *Utricularia*.

During the northeast monsoon (between September to January), Sungai Bera was not able to deal with the over water surface flow causing a seasonal flood and a reverse water flow into Bera Lake through several channels.

On the other hand, Putrajaya Lake is a man-made lake originated from an oil palm plantation into a wetland ecosystem. The wetland drains the Putrajaya Lake at a catchment area of 50.9 km^2 with water sources coming from Sungai Chua, Sungai Bisa and other three tributaries.

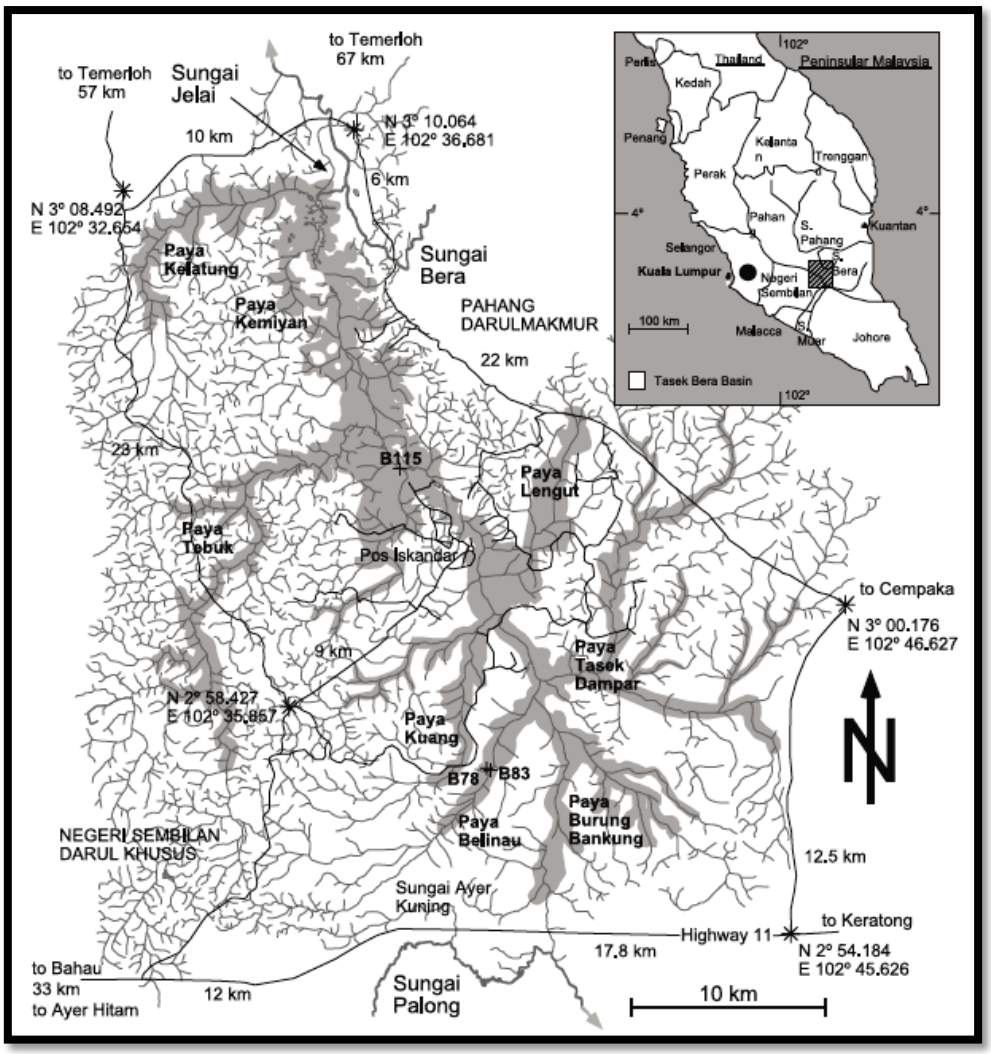

Figure 3.1 Location Map of Bera Lake

Putrajaya Wetlands are a multi-cell wetland system which was designed such that each of the cells is separated by a weir to have different water level at a range of 0.5 to 3.0m. The wetland which comprises 23 wetland cells (see Figure 3.2) covers 4 major habitats, (1) 39.4% of planted marsh area (2) 12.0% of intermittent inundation zone for swamp tree planting (3) 38.9% of open water (4) about 10% of weirs, islands and maintenance track. Vegetation types in the wetlands comprise emergent macrophytes (large plants), rheophytes (floating plants) and freshwater swamp species (Shutes, 2001).

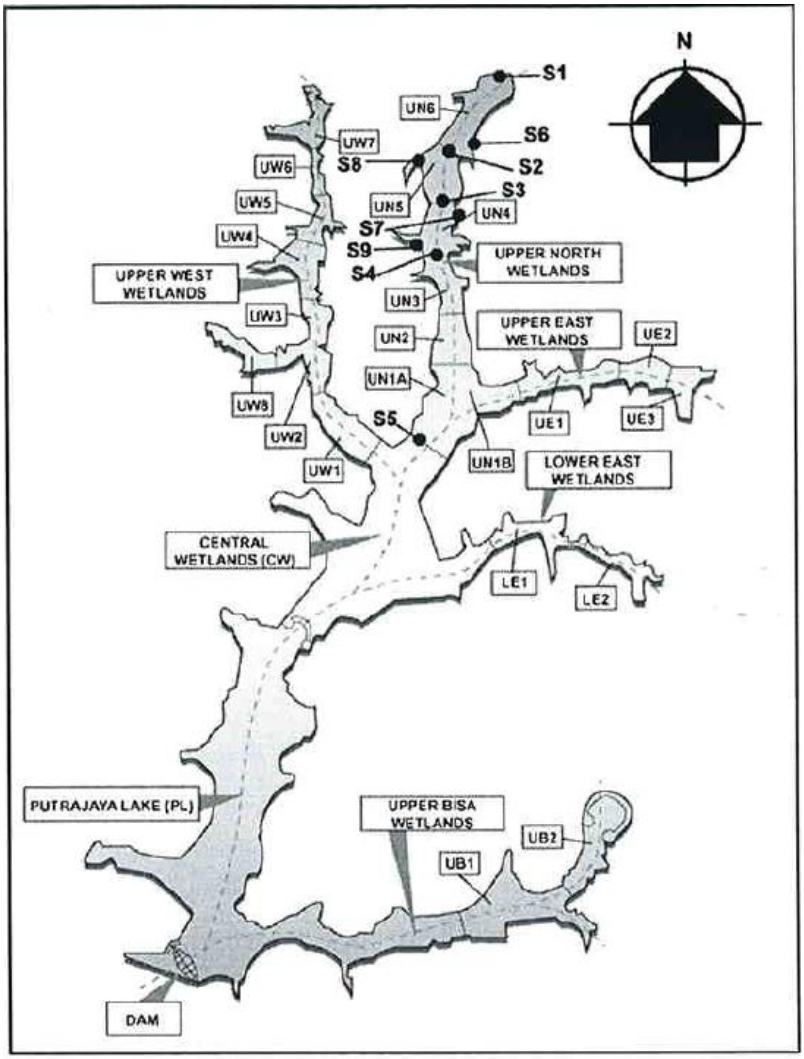

Figure 3.2 Location of wetland cells at Putrajaya Wetlands.

Table 3.1 provides the limnological details for both lakes.

Data for Bera Lake were taken at station 4PH72 whereas data for Putrajaya Lake were taken at 6 different stations, (1) UB (2) CW (3) LE (4) UE (5) UW and (6) UN. Size and storage area of all 6 stations for Putrajaya Lake were listed in Table 3.2. Raw data for both lakes were measured at irregular intervals and at different sampling dates thus interpolated data were used for consistency as required for development rule set models.

Limnological Variables	Bera Lake (2005-2009)			Putrajaya Lake (2006-2009)		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
Temperature ^{o}C	30.99	27.35	33.62	30.70	25.30	37.61
pH	6.40	5.59	7.60	7.44	6.19	8.85
Dissolved Oxygen mg/l	5.73	3.03	7.76	6.96	1.53	10.83
Conductivity µS/cm	49.48	31.00	190.00	81.53	1.20	1063.00
Salinity ppt	0.023	0.01	0.09	0.04	0.01	0.12
NH_3N mg/l	0.24	0.02	0.81	0.17	0.00	9.65
COD mg/l	26.20	1.00	49.0	13.32	1.00	67.00
BOD mg/l	2.24	17.00	6.00	1.57	3.00	10.00
PO_4 mg/l	0.13	0.01	1.00	0.05	0.00	2.08
NO_3 mg/l	0.118	0.01	0.31	0.93	0.0	5.09
Suspended Solids (NTU)	7.28	1.0	17.0	19.69	0.1	439.10

Table 3.1 Limnological properties of Bera Lake and Putrajaya Lake

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

Table 3.2 Size and storage capacity of Putrajaya Wetlands

3.2 Parameter Settings and Measures

The HEA application was applied to predict the dissolved oxygen dynamics for both Bera Lake and Putrajaya Lake. Daily input data for Bera Lake is biochemical oxygen demand (B.O.D), chemical oxygen demand (C.O.D), suspended solids, pH, NH_3NL, water temperature, conductivity, salinity, turbidity, dissolved solids, NO3, PO4, *E.coli* and coliform. Output data of dissolved oxygen concentration of year 2005 to 2008 were used as training data while data of year 2009 were used as testing.

For Putrajaya Lake, dissolved oxygen data for year 2006 to 2008 were used for training and data for year 2009 were used for testing the generalisation behaviour of the resulting rule sets. Daily input data under consideration is water temperature, pH, conductivity, salinity, phosphorus, nitrogen, suspended solids, *E.coli* and chlorophyll-*a*.

An iteration of 100 runs was performed for each data set on a supercomputer using programming language C. HEA parameter settings are listed in Table 3.3.

Structure Optimization (GP)	N=200 F_L={AND,OR} F_C={>, <, ≥, ≤} F_A={+, -, *, /, exp, ln} MAXK=4, D_{IF}=$D_{THEN/ELSE}$=4, MAXGEN=100
Parameter Optimization (GA)	popsize=50, a=-0.5, b=1.5 M=8 MAX=500

Table 3.3 Parameter settings of HEA for rule set discovery

Root mean square error (RMSE) (testing error) and fitness (training error) value were calculated to validate the result of different rule sets. Calculation was based on the following formula:

$$\sqrt{\frac{1}{m}\sum_{i=1}^{m}(\hat{y}_i - y_i)^2}$$

where;

m=number of testing data points

$\hat{y}_i$= ith observed value of dissolved oxygen

y_i = ith predicted value of dissolved oxygen