CHAPTER 2

ENVIRONMENTAL STUDIES

2.0 ENVIRONMENTAL STUDIES

2.1 OBJECTIVE

2.1.1 The major concern for the Putrajaya Lake system is that catchment development, particularly outside the Kawasan Putrajaya, may compromise the Lake water quality. This is because although development within the Putrajaya area may be administered to take into consideration the impact on the Lake water quality, current requirements applicable elsewhere may be inadequate for the purpose.

2.1.2 The purpose of the environmental studies, therefore, is

- to assess the impact of the current and future catchment landuse and activities on the Lake environment (Section 2.5).;
- to identify the current and future point and non-point pollutant sources of potential immediate and medium term impact, and trace pollutants of potential long term impact (Section 2.6);
- to describe the current ecological setting of the existing ponds and wetlands in the catchment and assess the effect of pollutant inflow on the wetlands (Section 2.7);
- to evaluate the capacity of the wetlands system developed to treat the non-point pollutants (Section 2.8);

2.1.3 Based on the above findings, the following recommendations are to be made:

- the pollutant loadings for all current, and future developments within the catchment and the desired loadings and effluent standards (Section 2.8);
- the management measures to mitigate and minimise the pollutant loadings into the Lake from the catchment area through the development of softscapes (Section 2.9, Appendix D);
- the appropriate effluent treatment, for the current and proposed development, that do not meet the desired pollutant loadings and effluent standards (Section 2.9.1);

- the best management practices to sustain the desired ecological balance in the constructed wetlands (Section 2.9.2, Appendix C);
- the existing ponds in the catchment with potential to be converted into a mini-wetlands and the implementation guidelines (Section 2.9.2, Appendix C);
- the best management practices for pesticide and fertilizer use in the catchment (Section 2.9.2, Appendix A, B);
- the water quality monitoring programme to be carried out (Section 2.10.2).

2.2 THE PHYSICAL SETTING

2.2.1 The Putrajaya Lake is formed by the impoundment of the Sg Chuau, through the

- the Sg Chuau river valley,
- capture of the upper section of Sg Limau Manis, and
- creation of a connecting channel between the captured Sg Limau Manis and the Sg Chuau river valley.

2.2.2 The catchment area of the Sg Chuau river up to the dam is 50.5 km^2, while for the captured portion of the Sg Limau Manis the catchment is approximately 1.5 km^2 (Table 2.2.1). There are eight major sub-catchments:

- Upper-North,
- Upper-West,
- Upper-East,
- Lower-East,
- Bisa,
- Central,
- Lower, and
- Limau Manis.

2.2.3 The surrounding land varies between 8 m to 152 m LSD, giving an undulating terrain over the catchment area. Steep uplands occur in the upper northwest and the east sector of the catchment with hills occurring in the northeast, west, and central sector.

Table 2.2.1 Catchment area of the Putrajaya Lake

Sub-Catchment	Area, km^2	% Total Lake	Landowners (in importance)	Current Landuse
Upper North (Sg Chuau)	12.4	23.1	UPM, MARDI, PPJ, IOI	Agricultural, Institutional, Residential, Parks, Golf course, Commercial, Health facility
Upper West (Sg Kuyoh)	6.2	11.5	MARDI, PPJ, TNB	Agriculture, Power station, Parks, Residential
Upper East	4.2	7.8	PPJ, UNITEN, West Country	Residential, Parks, Government, Institutional, Commercial
Lower East	1.7	3.2	PPJ	Residential, Parks, Government,
Central (Sg Chuau)	7.1	13.2	PPJ	Residential, Health facility, Parks
Upper Bisa (Sg Bisa)	5.9	11.0	PPJ	Residential, Parks, Government, Commercial
Lower (Sg Chuau)	14.7	27.4	PPJ, Cyberjaya	Residential, Commercial, Government,
Total Sg Chuau	52.2	97.2		
Captured Limau Manis	approx 1.5	2.8	PPJ	Residential, Government
Total Lake	53.7	100.0		

2.3 LANDUSE SETTING

2.3.1 The catchment area of the Putrajaya Lake lies within the administrative jurisdiction of the Majlis Daerah Sepang, Majlis Perbandaran Subang Jaya and Perbandanan Putrajaya.

2.3.2 Prior to the development of the Kawasan Putrajaya, the catchment area was primarily under oil palm plantation in the central portion with institutional and R&D development in the northern portion owned by MARDI and UPM. A power station is located in a small portion of the mid Upper-West sub-catchment.

2.3.3 The lower three-quarters of the catchment area are now being developed for the Federal Administrative Centre and associated commercial and residential premises. In addition, residential and golf course development has and is being undertaken in the lower Upper-North sub-catchment (by IOI) and mid Upper-East sub-catchment (by West Country).

2.3.4 The upper catchment areas are relatively undeveloped at present with experimental or non-intensive agricultural activities being carried out over the whole of the Upper-West sub-catchment and most of the upper portion of Upper-North sub-catchment. Only minor institutional facilities lie within the upper catchment areas. There is also a 9-hole golf course and a health centre within UPM. There are, however, several residential (hostel) premises within the Upper-North sub-catchment. These are expected to accommodate approximately 10,000 students in UPM.

2.3.5 Among the stakeholders,

1. MARDI plans to develop their land into a green lung with experimental incubator centres;

2. UPM plans to develop offices, sports complex, mixed housing, and a medical faculty building including a hospital;

3. IOI may be considered to have fully developed their land;

4. West Country is in the planning stage to develop low-density (approximately 2 lots/acre) residential properties;

5. TNB has completed their development;

6. UNITEN plans to develop institutional facilities;

7. Cyberjaya plans to have commercial and residential development;

8. Sungai Merab area is under individual ownership and there may be plans by each owner to develop their own property.

2.4 POLLUTANT INPUT SOURCES

2.4.1 Landuse and Pollution Potential

2.4.1.1 Pollution Potential Concept

(1) Pollutant input sources may enter the lake system from within or outside the Putrajaya Administrative Area. The designation of pollutant input sources may be based on landuse. This is because land use alters the drainage characteristics of the land and the activities carried out result in new pollutants being discharged.

(2) The greater the extent of urbanization the greater the change in drainage characteristics. Normally the amount of runoff and the speed of flow of runoff will increase. This reduces infiltration and retention of water over the ground. As retention time is reduced and flow increases, the pollution carrying capacity is increased.

(3) **Thus to reduce the impact of urbanization of the land,**

- **the amount of runoff needs to be reduced,**
- **runoff flow speeds needs to be reduced, and**
- **water needs to be retained on the land surface as long as possible.**

(4) There are many structural and non-structural methods to achieve this. One example is by the utilisation of detention

ponds. A guideline by the Drainage and Irrigation Department is that 3% to 5% of the total land area should be allocated for use as flood detention ponds.

(5) In addition to drainage changes, the type of activity carried out also affects pollutant inputs. The more intense the level of activity, the greater the possibility of pollutants being discharged. Different activities are associated with different types of pollutants. Some are natural pollutants which will degrade in the environment, such as organic wastes. Others may persist for long periods of time (some pesticides) or accumulate (heavy metals).

2.4.1.2 Pollutant Loadings

(1) Pollutant loadings in a catchment may be approached in two ways. The first is to consider that landuse may be regarded as a direct indicator of amount of pollutant released annually. Such values are given in weight or mass per unit area per year. The second approach is to estimate the concentration of the pollutant which is discharged out of the catchment. Either method is an approximation of the actual load because factors such as distance to receiver, land management measures, dilution effects, slope, etc are not taken into account. More sophisticated model are currently being developed using a combination of techniques, of hydraulics, hydrology, concentration measurements and topography in order to assess the pollutant loading. Many of the results of such estimates and calibration are site specific because of the many variables involved. In Malaysia, pollutant loading studies have primarily been on sediment loss through land clearing or disturbance.

(2) For this study, some information has been gathered on data used for temperate conditions (Table 2.4.1 and 2.4.2). The pollutant loading values previously calculated by Angkasa GHD (1996) for the Drainage Masterplan was also based on data calibrated for urban catchment in Australia (see Table 2.4.3).

Table 2.4.1 Estimated Annual Nutrient Loadings for Chesapeake Bay Watershed Model. N=Nitrogen, P=Phosphorous. Chesapeake Bay Program Office, June 1996.

Federal Lands	Developed	Forest park	Total
Acres	12,661	3,091	**15,752**
N lb/Acre	7.76	2.53	
Total N, lb	98,249	7,820	**106,069**
P lb/Acre	0.623	0.032	
Total P, lb	7,888	99	**7,987**

2.4.2 Point and Non-point Pollutant Sources

2.4.2.1 Different landuse types may also be used to identify the type of pollution source which may be expected as point or non-point sources.

2.4.2.2 **Point sources** may be easily identified to be those sources where

- there is a defined wastewater discharge point such as a pipe or channel, or
- where air is emitted from a defined point or building, or
- from where solid wastes can be collected from an defined point.

2.4.2.3 Point source pollution usually can be identified to come from commercial or industrial and sewage treatment plants, including houses or individual buildings.

2.4.2.4 **Non-point source** (NPS) pollution comes from many diffuse sources. It may be due to rainfall and the subsequent runoff moving over and through the ground. As the water moves along, it dissolves and carries away natural and man-made pollutants, depositing them into lakes, rivers, wetlands, and the ground water. Non-point source pollution can be an important factor for water quality deterioration since they can occur from large areas of land.

Table 2.4.2 Average Urban Stormwater Pollutant Loads (lbs./Year) in Bayfield, Wisconsin, USA. (Wisconsin Division of Natural Resources, Bureau of Watershed Management , April 1997)

	Residential 150.09 ac	**Commercial 54.59 ac**	**Industrial 9.45 ac**	**Institutional 42.75 ac**	**Open / Forest 14.59 ac**	**Total**
Solids	60036	103721	16537.5	27787.5	671.14	208753.1
Phosphorus	48.03	68.24	7.09	11.37	2.19	136.91
Ammonia	72.04	27.84	7.75	28.64	3.50	139.78
N02+N03	139.58	52.95	14.74	55.15	6.71	269.14
TKN	579.35	220	61.43	228.71	27.87	1117.35
BOD	5664.40	2150.3	599.98	2235.83	262.62	10913.12
COD	42558	16154.8	4507.5	16797.8	2042.6	82060.7
Chlorides	4549.23	1726.68	481.76	1795.50	204.26	8757.43
Sulfates	2640.08	1001.73	279.63	1041.82	116.72	5079.97
Magnesium	1523.41	578.65	161.41	601.49	0	2864.97
Silver	0.15	0.055	0.019	0.043	0	0.266
Lead	15	131	11.8	4.7	0	162.5
Copper	1.5	3.28	0.51	1.28	0	6.57
Zinc	36.02	61.14	9.92	6.41	0	113.50
Total PAH's	3	1.6	.4	1.6	0	6.7

Table 2.4.3 Putrajaya Modelled Future Pollutant Loads (Putrajaya Drainage Masterplan, 1996)

Water Quality Parameter	Lake		Wetland		Offsite	
	t/a	mg/L	t/a	mg/L	t/a	mg/L
Government Precinct						
Suspended Solids	1260	231	300	173	-	-
Total Phosphorus	2.6	0.5	0.7	0.4	-	-
Total Nitrogen	8.1	1.5	3.2	1.8	-	-
CBD Precinct						
Suspended Solids	1000	155	-	-	-	-
Total Phosphorus	2.4	0.4	-	-	-	-
Total Nitrogen	10	1.6	-	-	-	-
Residential Precinct						
Suspended Solids	1870	124	330	135	1850	160
Total Phosphorus	4.3	0.3	0.7	0.3	4.4	0.4
Total Nitrogen	18.2	1.2	3.7	1.5	20.9	1.8
Sport & Recreation Precinct.						
Suspended Solids	430	148	-	-	340	146
Total Phosphorus	1	0.3	-	-	0.8	0.3
Total Nitrogen	4.2	1.4	-	-	3	1.3

2.4.2.5 The pollutants involved include:

1. excess fertilizers, herbicides, and insecticides from agricultural lands, parks, and residential areas;
2. oil, grease, and toxic chemicals from urban runoff and energy production;

3. sediment from improperly managed construction sites, crop and forest lands, and eroding stream banks;
4. bacteria, viruses, and nutrients from livestock, wildlife, pet wastes, and combined sewerage systems;
5. pollutants from atmospheric deposition; and
6. modification of drainage systems.

2.4.2.6 Reduction and prevention of non-point source pollution include land management to reduce soil erosion by such methods as zoning or erosion control regulations, and the establishment of vegetated buffer zones.

2.4.2.7 Within the Putrajaya catchment boundary, the non-point sources may be given generally into the following four landuse types:

1. Green areas:
   Open spaces - Vegetated parks, experimental farms, orchards, pavements, golf courses;

2. Building areas:
   Offices - offices, institutional buildings, commercial businesses, health clinics;
   Medical/Chemical Centres - hospitals, laboratories;
   Residences - houses, flats, hostels;

3. Infrastructure:
   Transport - roads, highways, and bridges
   Drainage System - channels, streams, riparian areas, dams

4. Water bodies:
   Impounded Water - Lake, wetlands, retention ponds, riparian pools, buffer strips

5. Marinas - boats, jetties

2.4.2.1 Sources within Kawasan Putrajaya

(a) Landuse and Pollutants

(1) Point and non-point sources are identified within Putrajaya based on the landuse types (Table 2.4.4).

(2) In the Putrajaya Urban Design Guide Plan, 46 different land use

classes (Table 2.4.5) are identified. These may be grouped under the four landuse types and their pollution potential assessed. The pollution potential is based on a qualitative assessment of

- the possible intensity of use by people,
- the likelihood of ground disturbance or sediment introduction,
- the possibility of transitory pollutant sources (e.g. cars) being in the area, and
- the nature of materials and substances to be used in the area.

(3) Within Kawasan Putrajaya all interior building discharges are directed into a central sewage treatment system which discharges out of the catchment area. Therefore, sewage and most greywater does not present a problem in Kawasan Putrajaya.

(4) However, open areas such as residential gardens, car parks, roads, park areas, and the promenade, are not expected to be connected to the central system and these, therefore, are possible sources of pollution. The size and proximity of these areas to the lake will affect their possible impact on the Lake System.

(5) In addition, the presence of animals, whether pets, livestock, or wildlife, and their untreated wastes, can also introduce nutrients, and bacteria into the water bodies.

Table 2.4.4 Landuse as a Pollutant Source

Landuse Type	Pollutants Introduced			
	Nutrients	**Organics**	**Sediment**	**Metals**
Green areas				
parks, promenade	P, N	pesticide, herbicide, O&G	sediment, litter	metals in fertilizer, sediment
Building areas				
Offices Institutional buildings, commercial businesses, car parks	P, N, BOD	O&G	sediment, litter	metals in sediment
Medical/ Chemical Centres Hospitals, laboratories	P, BOD	clinical wastes		clinical wastes
Residences houses, flats, hostels	P, N, BOD	pesticide, herbicide, O&G	litter	
Infrastructure				
Transport Lines roads, highways, and bridges, reserves		herbicide, O&G	sediment, litter	metals in sediment
Drainage System Channels, streams, retention ponds, dams	transports P, N	transports pesticide, herbicide, O&G	transports sediment, litter	transports metals
Water bodies				
lake, wetlands, ponds, riparian areas	NH_3 stores P	stores pesticide, herbicide	stores sediment	stores metals
Marinas				
Boats	P	O&G	litter	metals in paint

Table 2.4.5 Landuse Type and Pollution Potential in Putrajaya

LanduseType	Pollution Potential		
	Low	Medium	High
GREEN AREAS			
Cemetery	x		
Metropolitan Parks	x		
Urban Parks		x	
City Parks		x	
Residential Pocket Parks		x	
BUILDINGS			
Offices			
Government Use	x		
Commercial		x	
Neighbourhood Commercial		x	
Mixed Use		x	
Civic and Cultural		x	
Public School Complex			x
Special School Complex			x
Postal		x	
Police		x	
Fire Brigade		x	
Mosque		x	
Other religious		x	
Library	x		
Public Facilities	x		
Information Centre	x		
Putrajaya Service Centre	x		
Service Industry		x	
Bus Depot			x
Sports and Recreation	x		
Water Reservoir/Treatment Plant		x	
Waste Water Facility		x	
Solid Waste Facility		x	
Substation		x	
Gas Supply Facility	x		
Utility Building	x		
Medical/Chemical Centres			
Health Facilities			x
(Laboratory)			x
Residential			
Residential		x	
INFRASTRUCTURE			
Transport lines			
TNB Reserve	x		
Telecommunication Facility	x		
Radio Site	x		
Gas Pipeline Reserve	x		
District Cooling	x		
Transportation Hub	x		
LRT Line/Station		x	
Park and Ride Station		x	
Road Reserve			x
Road Buffers		x	
Drainage system			
(Riparian buffer)	x		
(Drainage reserve)		x	

LanduseType	Pollution Potential		
(Detention ponds)		x	
WATER BODIES			
Promenade	x		
(Riparian parks adjoining Lake)	x		
Wetlands		x	
Lake/Water body		x	
MARINAS			
(Marinas)			x

(6) The more important aspects of landuse and associated activities in Putrajaya are:

a) the presence of buildings and associated impermeable surfaces, allowing higher runoff and lowered retention over the ground;

b) large green areas for public parks which may be potential sources of fertilizers and pesticides, if uncontrolled;

c) the location of bridges and roadways close to the open water, which may be sources of oil and grease, sediment and associated metals, and litter;

d) boating activity which will be sources of oil and grease, metals and toxic paints;

e) the development of the lake edge within 30 m of the shoreline in a manner which may not act to reduce runoff flow velocities or trap materials carried by runoff.

(7) The most important pollutants of concern which may be linked to landuse practices and activities are, in order, sediments, phosphorus, nitrogen, organic solvents, such as oil and grease, and agricides.

(b) Construction Sites

(1) Construction sites are important sources of sediment into the waterways and Lake system. Improperly planned and managed land clearing activities expose soil to natural forces of wind and rain, allowing the surface soil to be transported as dust or suspended and bedload sediment. It is therefore extremely important to ensure adequate soil erosion control measures,

proper drainage of the construction site, and correct placement of silt traps.

(2) In the Putrajaya Lake Management Guide several measures were proposed and are also relevant and should be applied also to areas outside of Putrajaya to protect waterways leading into the Lake and wetlands.

(3) The measures are:

- implementing infiltration design measures and green corridors along waterways (Appendix D);
- installation of rubbish and pollutant trapping structures along the stormwater drainage system;
- creation of riparian systems along water courses;
- creation of grassed swales around the lake perimeter at grassed areas, and infiltration drains in constructed areas.

(4) The following measures are to be taken during construction activities:

- To protect the lake quality, during construction phase it is important to ensure only necessary and for immediate need earthworks are carried out. Earthworks should only be prepared for projects within 6 months of expected use for construction;
- Silt traps are to be sized, based on the daily rainfall record at Putrajaya Catchment, to the one in five-year rainfall or greater;
- Silt trap maintenance operation is to be regularly scheduled;
- A radius of 100m grassed/ forested buffer strip between any portion of the dammed part of the lake and any other project development earthworks is to be maintained;
- This grassed/ forested strip may subsequently be developed for individual projects. If grassed, the grass should be long, or deep layer of cover crop. The purpose is for increased surface roughness and retard overload flow velocities, thereby encouraging sedimentation.
- Within the 100m grassed/ forested strip surrounding the lake, the maximum area of earthworks which is to be carried out at any one time should not exceed 0.5ha within a 1km distance;

(5) In addition,

- A minimum radius of 3m grassed/ turfed strip from any drainage channel leading to silt traps, 8m for natural streams, and any project development earthworks is to be maintained. Not more than 50m distance next to the stream/ drain cleared/ worked at any one time. The cleared earth should be turfed/ grassed over before another 50m is cleared/ worked.

(6) Reference may be made to the Erosion Control Guidelines of DOE, the Urban Design Guidelines, and the Drainage Design Masterplan for Putrajaya.

(7) The soil erosion potential for the Putrajaya Catchment has been defined and discussed in Section 3.2 in Volume 2 of the Main Report. They should be referred to especially for construction and earth clearing activities. Greater care would need to be taken in the high erosion potential areas.

(8) Perbadanan's experience has shown that there is extreme difficulty in ensuring that all silt trap and drainage designs for construction sites are adequate to prevent sediments entering the waterways. In this respect, it is recommended that a new "Erosion and Sediment Control By Law" be enacted by the Perbadanan Putrajaya and Majlis Daerah Sepang. The recommended By-Laws needs to be supported by a new manual detailing procedures, work order, and design standards for erosion and sediment control. The manual should detail the specifications and design or erosion and sediment control measures and works.

(c) Phosphorus

(1) As far as lake health is concerned, the most important chemical parameter of concern is phosphorus. Phosphorus is one nutrient essential for plant growth. Another nutrient is Nitrogen. In the natural environment, nitrogen concentrations are normally in abundance while phosphorus concentrations are usually very low.

(2) Phosphorus in natural waters may be divided into several forms. The description given below is taken from Chapra (1997). One

method of dividing the different forms of Phosphorus is related to the analytical methods available. Figure 2.4.1 shows the relationship between the different forms.

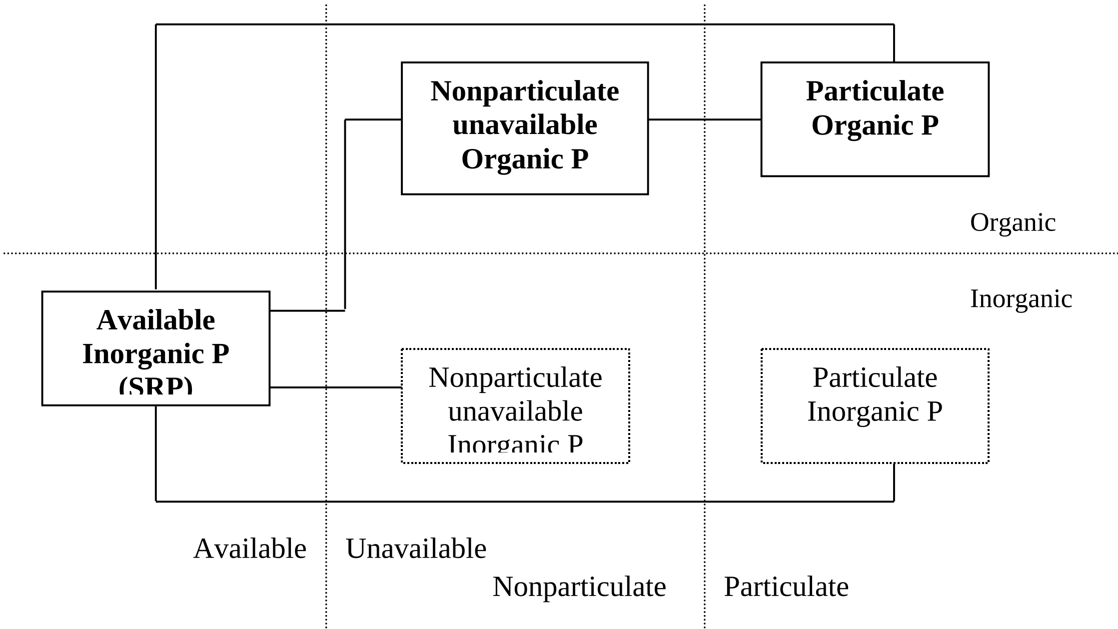


Figure 2.4.1 Different forms of phosphorus found in natural waters. (The main forms contributing to the plant life cycle is indicated in bold lines).

(3) The Total Phosphorus analysis measurement is widely used to assess euthrophication. It gives a measure of all available Phosphorus which might be available for plant growth in future. However, for measuring present plant growth the measure of the SRP or available dissolved P, is a more meaningful measure. It is therefore recommended that for assessing long term euthrophication potential, the Total Phosphorus measure be used but that for the existing status of plant growth potential, then the available dissolved phosphorus be measured.

from Chapra 1997.

Soluble reactive Phosphorus (SRP). Also called orthophosphate or soluble inorganic P, this is the form that is readily available to plants. It consists of the species $H_2PO_4^-$, HPO_4^{2-} and PO_4^{3-}.

Particulate organic P. This form mainly consists of living plants, animals, and bacteria as well as organic detritus.

Nonparticulate organic P. These are dissolved or colloidal compounds containing phosphorus. Their primary origin is the decomposition of particulate organic P.

Particulate inorganic P. This category consists of phosphate minerals (e.g. on clays), and phosphate complexed with solid matter. This group includes condensed phosphates such as those found in detergents.

The distinction between particulate and non particulate forms is made so that the former can selectively be removed (from the analysis) by setting. The division of available phosphorus from the other species is made because it is the only form that is directly available for plant growth. It should be understood that the other forms are not absolutely "unavailable". Rather, they must first be converted to SRP before they can be consumed by plants.

(4) Thus Phosphorus is usually regarded as a limiting factor to growth. When Phosphorus levels are high it leads to increased plant growth. It is therefore of paramount importance to prevent the inflow of phosphorus into the system. In this respect, the sources of phosphorus in the catchment may be given to point sources and non point sources. The point sources are from sewage treatment systems and the non point sources are from land use activities, such as the use of fertilizers, land development and drainage system changes, and from soil erosion.

(5) Point sources inputs are dealt with in the Sewage Master Plan section of the Main Report while non point sources are dealt with in this study. Recommendations are made on controlling non point source pollutants through the establishment of buffer zones and through issuance of guidelines on fertilizer use in the catchment.

(d) Trace Pollutants

(1) Most of the pollutants mentioned above are formed of natural compound readily found in the environment, thus they will degrade in time, such as organic wastes. Other pollutants, although also naturally occurring may persist for long periods of time (organic compounds such as in pesticides, solvents) or accumulate (heavy metals). These are usually present in very low concentrations, ppb and ppm levels, are usually complicated to measure and usually cause toxic effects. These pollutants may be regarded as trace pollutants which need to be monitored because the Lake system functions as a sink for them to accumulate in. As they are normally in very low concentrations, however, their accumulation to produce toxic effects normally occur over a period of tens of years rather than months. Therefore they need only be monitored every year or twice a year at most. The trace pollutants include but are not limited to the list in Table 2.4.6.

(e) Accidental Spillages

(1) Pollutants may also enter the Lake system through accidental spillages of oil or chemicals from the promenade or, more importantly, from roads and bridges crossing the Lake and Wetlands. In such a case an Emergency Response Plan, ERP, will need to be initiated to reduce the amount of pollutant entering the water, to contain the spillage already in the water, and to recover or neutralise the pollutant spill in the water.

(2) The formulation, control, and command of the ERP must be coordinated among the Lake and Wetland Management Unit, the Environment Unit, the Marine Police, the Fire Department as well as the Traffic Police and the road, bridge, or highway Operator. The participation of the pollutant owner is of course necessary in the implementation of the Plan.

(3) In order to reduce such likelihood of spills entering the wetlands, however, road or bridge side containment vessels or channels should be incorporated into the design of the utility.

Table 2.4.6 Possible Trace Pollutants in Putrajaya Lake

Trace Pollutant	Unit	Putrajaya Ambient Lake Water Quality Standards
Metals		
Aluminium	mg/l	<0.05 if pH<6.5* <0.1 if pH>6.5
Arsenic	mg/l	0.05
Antimony	mg/l	0.03
Beryllium	mg/l	0.004
Cadmium	mg/l	0.002
Chromium, Total	mg/l	0.05
Copper	mg/l	0.02
Cyanide	mg/l	0.02
Lead	mg/l	0.05
Mercury	mg/l	0.0001
Nickel	mg/l	0.02
Selenium	mg/l	0.01
Silver	mg/l	0.05
Radioactivity		
Gross-alpha	Bq/l	0.1
Gross-Beta	Bq/l	1
Radium-226	Bq/l	<0.1
Strontium-90	Bq/l	<1
Organics		
Carbon Chloroform extract	ug/l	500
MBAS/BAS	ug/l	500
PCB	ug/l	0.1
Phenol	ug/l	10
Aldrin/Dieldrin	ug/l	0.02
BHC	ug/l	2
Chlordane	ug/l	0.08
t-DDT	ug/l	0.1
Endosulfan	ug/l	10
Heptachlor/Epoxide	ug/l	0.05
Lindane	ug/l	2
2,4-D	ug/l	70
2,4,5-T	ug/l	10
2,4,5-TP	ug/l	4
Paraquat	ug/l	10

2.4.2.2 Sources From Outside Kawasan Putrajaya

(1) Pollutant sources from outside the Putrajaya area also can be classified in the same manner as for Putrajaya. Table 2.4.7 shows the pollution potential associated with the current landuse.

(2) Within the upper catchments of Upper-West and Upper-North, much of the land is covered with grass or under tree-cover, with orchards, rubber trees and small experimental plots. There is a nine-hole golf-course in UPM. There are no major drainage works and the small streams have slight to moderate vegetation growth within them, which act as filters and absorbers of nutrients, organics, and sediment which are carried by the streamflow. The major pollutant input from such areas is of non-point sources and are nutrients and organics..

(3) There are few buildings in the smaller Upper-West sub-catchment. These are served by septic tank systems. The Upper-North Catchment is larger and more developed. There are several hostels in UPM and these are on individual treatment systems. In the middle section of the catchment, there are residential developments with individual treatment systems, and a golf course. There are also new residential developments being proposed by West Country. All the treatment systems for the developments are point sources (Table 2.4.8). The details on the systems are presented in Chapter 5. There is a possibility that some of the discharges will be pumped out of the catchment. The major pollutants are organic wastes, phosphorus, and bacteria. The golf course is a non-point source of nutrients and pesticides.

(4) In the Upper-East sub-catchment, UNITEN is likely to develop the land for institutional facilities. Any buildings with treatment systems will be point sources.

(5) In the Lower sub-catchment, the proposed developments of Cyberjaya will result in point source pollutants from the treatment system. It is possible that the discharge will be pumped out of the catchment, however.

Table 2.4.7 Landuse and Pollution Potential from External Sources

LAKE CATCHMENT AREA (Acre)	UPM %	MARDI %	IOI %	TNB %	WEST COUNTRY %	CYBER JAYA %	SUNGAI MERAB %	UNITEN %	TOTAL %	Pollution Potential		
										Low	Medium	High
GREEN AREAS												
Open space/Fields	20.06	3.33	2.61	0.00	0.00	100.00	0.00	0.00	12.28	x		
Golf Course	17.83	0.00	97.39	0.00	0.00	0.00	0.00	0.00	13.63		x	
Farms	20.45	58.00	0.00	0.00	0.00	0.00	0.00	0.00	25.26		x	
Orchards	41.66	38.67	0.00	0.00	0.00	0.00	0.00	0.00	26.74		x	
Others	0.00	0.00	0.00	100.00	100.00	0.00	100.00	100.00	22.09	x		
% of Total	75.26	76.37	42.59	87.02	100.00	19.32	100.00	100.00	67.16			
BUILDINGS												
Administration/Offices	0.00	61.13	0.00	0.00	0.00	27.40	0.00	0.00	19.35	x		
Hostels	36.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.41			x
Housing/Quarters	2.21	16.59	82.14	0.00	0.00	50.00	0.00	0.00	38.90	x		
Commercial	0.00	0.00	10.86	0.00	0.00	5.01	0.00	0.00	4.17		x	
Power Station	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	4.07		x	
Facilities	60.90	0.00	7.00	0.00	0.00	15.02	0.00	0.00	20.60		x	
Others	0.00	22.28	0.00	0.00	0.00	2.49	0.00	0.00	4.50	x		
% of Total	11.66	9.66	30.77	12.98	0.00	39.96	0.00	0.00	16.13			
WATER BODIES												
Pond/Lake	100.00	100.00	14.29	0.00	0.00	100.00	0.00	0.00	52.13		x	
Wetland	0.00	0.00	85.71	0.00	0.00	0.00	0.00	0.00	47.87		x	
Total	1.74	2.66	21.41	0.00	0.00	8.40	0.00	0.00	4.98			
INFRASTRUCTURE												
Roads/Drainage	39.07	39.14	89.63	0.00	0.00	24.58	0.00	0.00	36.26		x	
Express Rail Link	46.87	35.47	0.00	0.00	0.00	18.23	0.00	0.00	30.53		x	
Highway	14.06	25.39	0.00	0.00	0.00	41.72	0.00	0.00	26.79		x	
Others	0.00	0.00	10.37	0.00	0.00	15.47	0.00	0.00	100.00		x	
% of Total	11.34	11.31	5.23	0.00	0.00	32.32	0.00	0.00	11.74			
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00			
TOTAL AREA	1389.80	1204.58	522.91	222.98	276.37	607.04	89.60	93.80	4407.08			

Table 2.4.8 External Point Sources

Landowner	Source Type	Current	Future
MARDI	Office Septic Tank	4	
	House Septic Tank	approx . 20	
UPM	Hostel Septic Tank	2	
	Hostel Hi-Kleen	(1)	
	Hostel Sewage Treatment Plants	2	
	Student Health Centre	1	
	Cafeteria	1	
	Office/Laboratory Septic Tank	4	
IOI	House Septic Tanks	0	
	Office Septic Tank	2	
	Sewage Treatment Plant	1	1
West Country	Sewage Treatment Plant	0	1
UNITEN		0	
Sungai Merab		0	
Cyberjaya	Hi-Kleen Treatment Plant	1	0

( ) - under construction.
Future denotes known plans.

(6) The small Limau Manis sub-catchment includes some lots in the Sungai Merab area. The waste treatment systems of the houses to be developed will be point sources.

2.5 ASSESSMENT OF POLLUTANT IMPACT TO PUTRAJAYA LAKE SYSTEM

2.5.1 Upper-West Sub-Catchment

2.5.1.1 The land in this catchment is owned by MARDI and TNB. This catchment is drained by Sg. Kuyoh into the Upper-West wetlands. A small portion of the wetland tributary intrudes into TNB land. The wetlands are crossed at the northern end by the South Klang Valley Expressway (B11) and the ERL.

2.5.1.2 Much of the land is under non-intensive agriculture and forest. Only a small number of buildings exist here comprising worker quarters and low-rise office blocks.

2.5.1.3 The streams are small, less than 2 m width at low flow, and shallow (1 m). The streams enter a constructed pond approximately in mid-catchment and receives most of the artificial stormwater drainage as well as septic tank overflow in MARDI.

2.5.1.4 At present only about 1,000 persons work on the whole in the MARDI area with only a few hundred residents. The future working population is not expected to increase beyond 2,000 persons.

2.5.1.5 The sewage contribution from here is low (with less than 2,000 persons). What was of major concern previously was the rearing of a large population of farm animals on the site and the resultant wastes. Due to the presence of the Putrajaya development, the animals had been relocated elsewhere and the farm section is expected to be closed down shortly. Any future animal rearing is expected to be dispersed and of small numbers. The numbers planned are unknown at this stage but are expected to be less than 100.

2.5.1.6 The stream waters are clear and it is expected that any nutrients washed off in runoff would be mostly taken up by the many plants lining the stream. During storm events, however, it is likely that this uptake will be reduced as flow velocities increase.

2.5.1.7 In their future development plans, MARDI has proposed the development of additional ponds in the lower part of their catchment. This should be able to increase the retention of water and enhanced nutrient uptake.

2.5.1.8 The pesticides used in MARDI are of the soluble type and non-persistent, quickly degrading in the environment. Application is controlled and follows the guidelines of the Department of Agriculture. Since the agriculture practised is non-commercial, dispersed and of small size, it is not expected that agro-chemicals will be an issue from this catchment.

2.5.1.9 In the TNB sector of the catchment, routine monitoring of discharges is carried out as required by the Department of Environment. Their reports indicate that all discharges comply to the regulations. The discharges from this sector are not expected to be an issue.

2.5.1.10 The southern sector of what was MARDI land, however, has been acquired for the development of the South Klang Valley Expressway (B11) and the ERL. It is expected that the construction activities from this development will contribute to increased sediments in the streams and release of soil-bound phosphorous.

2.5.1.11 At present, the Kajang-Puchong (B11) road crosses the wetlands. The risk of traffic accidents from cars, lorries and fuel tankers is always present. At present there are no buffers or barriers on either side of the road to prevent fuel spillages from flowing into the lake.

2.5.1.12 In summary,

- nutrient input current (measured Total Phosphorus concentrations are approximately 0.4 - 5 mg/l) and future is minimal;
- fertilizer, pesticide input is controllable;
- no large flow input variations (<30%) are expected in future;
- sewage input (<0.003 m^3/s) is insignificant because of the low population;
- pollutant input from the road crossing the wetland is possible.

2.5.1.13 The recommendations for this catchment are primarily to enhance the landuse setting:

- maintain streams and introduce riparian buffer strips (non-point BMP);
- ensure dispersed development in the catchment with higher intensity development, if required, upstream of detention ponds;
- maintain forested areas in steep slopes to the north-northwest of the catchment;

- landuse changes and development should occur in stages, planned to extend over 8 to 10 years to allow for monitoring and re-evaluation of impacts. Land earthwork clearing should not extend over more than 15% of the catchment at any one time and preferably less than 10% in a 6 month period.

2.5.1.14 Of immediate concern is the need to

- install mitigating measures to prevent pollutant input from the roads crossing the wetland.

2.5.1.15 The proposed future development of the area in MARDI as a “green lung” is in line with the maintenance of the Putrajaya Lake environment.

2.5.1.16 The current development at TNB is not expected to alter and currently contributes no significant pollutant input to the Lake. The risk of explosion is the only concern but is unlikely to affect the Upper-West wetlands directly. There is an approximately 200 m distance from the station proper to the station boundary.

2.5.2 Upper-North Sub-Catchment

2.5.2.1 MARDI, UPM and IOI own the land in this catchment which is drained by Sg. Chuau into the Upper-North wetlands. It is twice the size of the Sg. Kuyoh Upper-West catchment at 12.4 km^2. The South Klang Valley Expressway and the ERL cross the wetlands at the northern end.

2.5.2.2 Much of the land is under vegetation with some farms, orchards, and two golf courses. The northeastern portion is covered by oil palm and rubber. There are institutional buildings, including laboratories, a student health centre, offices, hostels, and a number of constructed ponds.

2.5.2.3 The streams are small, less than 1 m width at low flow and shallow. The streams do not enter any of the ponds.

2.5.2.4 Besides the small working population in MARDI, there are about 10,000 students in UPM, and a small residential population in IOI. In MARDI and IOI the population is unlikely to change by more than 1,000. In UPM, the future working and residential population is uncertain. The student hostel population may increase slightly but unlikely to be more than 3,000. This is based on the proposal to build a Medical Faculty with housing, a sports complex, and some mixed development within the catchment.

2.5.2.5 At present the sewage contribution from here is low but of much greater amounts than in the Upper-West catchment. All septic tank outflows, serving a population of about 3,000, discharge into a stream tributary in the upper part of the catchment. The High Clean system discharges into one of the constructed ponds also in the upper part of the catchment.

2.5.2.6 By the time the stream reaches the boundary with Putrajaya, the waters are clear and it is expected that there has been some natural biodegradation of the organic wastes. During low flow any nutrients in the water will probably be taken up by the small number of plants lining the stream. During storm events, however, it is likely that the fast-flowing runoff and septic tank overflow will worsen water quality. This will be balanced with dilution effects.

2.5.2.7 In IOI the individual bungalow lots are served by septic tank systems. Some discharge into storm drains directly draining into the Upper-West while the rest drain into a pond before entering into the upper section of the Upper-West.

2.5.2.8 The use of fertilizers and pesticide is expected to be limited. The agriculture practised here is non-intensive, and of small size, mainly being student farms. It is not expected that agro-chemicals will be an issue due to this activity. However, because of the nature of the agriculture practised the chemical use is not centrally controlled. Therefore, there must be controls and monitoring of the chemicals used.

2.5.2.9 There are two golf courses within the catchment area and fertilizer and herbicide use on the grounds may be of concern. Usually there are many internal ponds which help to capture most of the chemicals and these may be used to monitor fertilizer use. In addition, however, the downstream borders of the golf course should be designed to function as runoff buffers to reduce overland flow of the chemicals. Grass should be allowed to grow or swales introduced to streamline flow and increase retention time. In addition use of herbicides, in an effort to control vegetation growth, should not be encouraged along streams and water courses. Manual gardening methods should be used instead, if necessary.

2.5.2.10 The future development of MARDI follows the concept of "green lung" and is in line with the issues discussed for the Upper-West catchment.

2.5.2.11 In their future development plans, UPM has proposed several different types of development. These include institutional and recreational facilities. There is also a proposal to develop a Medical Faculty and teaching hospital. This latter development is of some concern because of the issue of clinical waste.

2.5.2.12 In the IOI sector of the catchment, no further development is expected.

2.5.2.13 In this catchment too, the southern sector of what was MARDI and UPM land, has been acquired for the development of the South Klang Valley Expressway (B11). In the eastern sector, there are proposal to upgrade the existing Serdang-Kajang road It is expected that the construction activities from these developments will contribute to increased sediments in the streams and release of soil-bound phosphorous

2.5.2.14 Similar to the case for the Upper-West wetlands, the Dengkil-Puchong road crosses the wetlands. The risk of traffic accidents from cars, lorries and fuel tankers is always present. There are presently no buffers or barriers on either side of the road to prevent fuel spillages from flowing into the lake.

2.5.2.15 In summary,

- current nutrient input is small (measured phosphate concentrations are approximately);
- fertilizer and pesticide input needs to be controlled and monitored;
- some flow input variations are expected due to future developments;

- sewage input is small (see above) but of concern as they are currently only treated through septic tank systems;
- golf course maintenance may be a source of nutrients and chemicals;
- pollutant input from the road crossing the wetland is possible.

2.5.2.16 The recommendations for this catchment are to improve water quality in streams:

- enhance and introduce riparian buffer strips (non-point BMP);
- utilise constructed ponds to retain drainage and stream flow;
- development in the catchment should grade from lower intensity near streams to higher intensity development, if required, upstream of detention ponds;
- adequacy of the current and future sewerage treatment systems needs to be addressed;
- the constructed ponds may be used as discharge points for sewage treatment systems before overflow to streams;
- medical/laboratory wastes should be discharged out of the catchment;
- landuse changes and development should occur in stages, planned to extend over 8 to 10 years to allow for monitoring and re-evaluation of impacts. Land earthwork clearing should not extend over more than 15% of the catchment at any one time and preferably less than 10% in a 6 month period.

2.5.2.17 Of immediate concern is the need to

- ensure optimum function of the current sewage treatment system;
- install mitigating measures to prevent pollutant input from the roads crossing the wetland.

2.5.2.18 The proposed future development of the area can be sustained provided:

- fertilizer and pesticide use is controlled and monitored;
- adequate sewage treatment facilities are installed;

- medical and laboratory wastes are exported from the catchment.

2.5.3 Upper-East Sub-Catchment

2.5.3.1 Perbadanan Putrajaya, West Country and UNITEN own the land in this catchment. The sub-catchment is only 4.2 km^2. This catchment drains into the Upper-East wetland.

2.5.3.2 West Country has two separated land lots in the mid and upper catchment, while the UNITEN land is only in the upper catchment. At present the land is under rubber forest.

2.5.3.3 The development plan for the upper catchment lot of West Country is for low density (2 lots/acre) residential development. A similar development is proposed for the mid catchment lot. The mid catchment lot directly borders the Upper-East wetland.

2.5.3.4 In their future development plans for the upper catchment lot, West Country has proposed the development of detention ponds following the DID guidelines. These ponds should be able to increase the retention of water and allow for sedimentation and nutrient uptake.

2.5.3.5 For the upper catchment lot, West Country have elected to pump out all sewage from the single sewage treatment plant in the catchment. Only the sewage from the mid-catchment lot will be of concern.

2.5.3.6 For the upper catchment area of UNITEN, it is expected that the development will be for institutional purposes.

2.5.3.7 In summary,

- nutrient, fertilizer, pesticide input is currently negligible with some small increase expected in future ;
- some flow input variations are expected due to future developments;
- sewage input is small because of the small population but may be of concern because of the proximity to the wetland.

2.5.3.8 The recommendations for this catchment are related to development issues:

- introduce riparian buffer strips (non-point BMP) along drainage lines;
- adequate sewage treatment measures need to be developed;
- treated sewage discharges should enter upstream of detention ponds;
- earthwork clearing should follow the guidelines applied within Perbadanan Putrajaya.

2.5.3.9 There are no immediate concerns as the land is under rubber forest at present.

2.5.3.10 The proposed future development of the area can be sustained provided:

- fertilizer and pesticide use is controlled and monitored;
- riparian buffers are installed along drainage lines and the wetland shoreline;
- adequate sewage treatment facilities are installed.

2.5.4 Central Sub-Catchment

2.5.4.1 The Central sub-catchment includes input from Cyberjaya. Land is owned by Perbadanan Putrajaya also.

2.5.4.2 The sewage contribution from here is expected to be low. However, since the discharge is to the downstream portion of the lake it is a matter of great concern. It is understood that Cyberjaya intends to export the sewage discharge.

2.5.4.3 In their future development plans, Cyberjaya should include the development of detention ponds in the lower part of their catchment. This should be able to increase the retention of water and enhanced nutrient uptake.

2.5.4.4 The pesticides used are expected to be of small amounts. It is not expected that agro-chemicals will be an issue from Cyberjaya.

2.5.4.5 Construction activities for development in this area is expected to be of concern. It will contribute to increased sediments in the streams and release of soil-bound phosphorous. Shoreline development should be completed prior to Main Dam closure. Earthworks should follow the guidelines within Putrajaya.

2.5.4.6 In summary,

- nutrient, fertilizer, pesticide input is currently negligible with some small increase expected in future ;
- some flow input variations are expected due to future developments;
- sewage input is small because of the small population but may be of concern because of the proximity to the wetland.

2.5.4.7 The recommendations for this catchment are related to development issues:

- introduce riparian buffer strips (non-point BMP) along drainage lines;
- adequate sewage treatment measures need to be developed;
- treated sewage discharges should enter upstream of detention ponds;
- earthwork clearing should follow the guidelines applied within Perbadanan Putrajaya.

2.5.4.8 The immediate concern is

- development of the Lake shoreline before Main Dam closure;
- sewage discharge into the catchment.

2.5.4.9 The proposed future development of the area can be sustained provided:

- fertilizer and pesticide use is controlled and monitored;
- shoreline and riparian buffers are planned along drainage lines and the Lake;
- adequate sewage treatment facilities are installed.

2.5.5 Limau Manis Sub-Catchment

2.5.5.1 The Limau Manis sub-catchment, which is the result of the capture of an upper section of the Sg Limau Manis, includes a small portion of the Sungai Merab village.

2.5.5.2 At present the land is under forest.

2.5.5.3 In summary,

- nutrient, fertilizer, pesticide input is currently negligible with some small increase expected in future ;
- some flow input variations are expected due to future developments;
- sewage input is expected to be small because of the small area.

2.5.5.4 The recommendations for this catchment are related to development issues:

- adequate sewage treatment measures need to be developed. As this is a small catchment with a small number of lots, Perbadanan Putrajaya should consider connecting the lots to the Putrajaya Central Sewage Treatment line.

2.5.5.5 The immediate concern is

- the rate of development of the lots is unknown.

2.5.5.6 The proposed future development of the area can be sustained provided:

- fertilizer and pesticide use is controlled and monitored;
- adequate sewage treatment facilities are installed.

2.5.6 Summary of Sources of Pollutant Potential and Recommendations

Sub-Catchment	Sources of pollutants	Recommendations
Upper West	• nutrient input • fertilizer and pesticide input • flow input variations • sewage input • pollutant input from the road crossing the wetland	• maintain streams • introduce riparian buffer strips • ensure dispersed development in the catchment • maintain forested areas in steep slopes • landuse changes and development should occur in stages • Land earthwork clearing should not extend over more than 15% of the catchment at any one time • install mitigating measures to prevent pollutant input from the roads crossing the wetland.
Upper-North	• nutrient input • fertilizer and pesticide input • flow input variations • sewage input - septic tank systems; • golf course maintenance - source of nutrients and chemicals; • pollutant input from the road crossing the wetland is possible.	• enhance and introduce riparian buffer strips • fertilizer and pesticide use is controlled and monitored; • utilise constructed ponds to retain drainage and stream flow; • ensure dispersed development in the catchment • the constructed ponds may be used as discharge points for sewage treatment systems before overflow to streams; • medical/laboratory wastes should be discharged out of the catchment; • landuse changes and development should occur in stages, • Land earthwork clearing should not extend over more than 15% of the catchment at any one time • ensure optimum function of the current sewage treatment system; • install mitigating measures to prevent pollutant input from the roads crossing the wetland.

Upper-East	• nutrient, fertilizer and pesticide input • flow input variations • sewage input	• introduce riparian buffer strips (non-point BMP) along drainage lines and wetland shorelines; • fertilizer and pesticide use is controlled and monitored; • adequate sewage treatment measures need to be developed and facilities installed; • treated sewage discharges should enter upstream of detention ponds; • earthwork clearing should follow the guidelines applied within Perbadanan Putrajaya.
Central	• nutrient, fertilizer and pesticide input; • flow input variations • sewage input – proximity to the wetland.	• introduce riparian buffer strips (non-point BMP) along drainage lines and wetland shorelines; • fertilizer and pesticide use is controlled and monitored; • adequate sewage treatment measures need to be developed and facilities installed; • treated sewage discharges should enter upstream of detention ponds; • earthwork clearing should follow the guidelines applied within Perbadanan Putrajaya. • development of the Lake shoreline before Main Dam closure;
Limau Manis	• nutrient, fertilizer, and pesticide input • flow input variations • sewage input	• fertilizer and pesticide use is controlled and monitored; • adequate sewage treatment measures need to be developed and facilities installed and connected to the Central Sewage Treatment line.

2.6 WATER QUALITY MODELLING

2.6.1 Introduction

In order to ensure that the water quality in the Putrajaya Lake system meets the Putrajaya Lake Water Quality Standard, there is a need to continuously manage and monitor the water quality in the system. Also, to assess the pollutant-carrying capacity of the Putrajaya Lake system there is a need to model the water quality of the system for various scenarios of discharge and pollutant input into the system.

2.6.2 Water Quality Monitoring

(1) For a development project, monitoring may be divided into three stages:

1. baseline or pre-construction;
2. construction and commissioning;
3. operation or post-construction.

(2) Putrajaya Holdings Sdn. Bhd., the main developer in Putrajaya, is currently monitoring the water quality in the Putrajaya Lake system through the various development contractors.

(3) At present, the wetlands and Phase 1A of the lake is in the commissioning stage. Therefore only two stages of monitoring had been carried out by them. There are also information on water quality of the area from several previous studies.

2.6.2.1 Baseline stage and pre-construction

A. Baseline Information

(1) The previous water quality samplings undertaken in the Sungai Chuau catchment was summarised by Perunding Kota Bistari (1996) in its Water Quality Control and Management Study on the Putrajaya Lake Development. The data reviewed and summarised were from the following studies:

1. The Geological and Geotechnical Study (JPK, 1994)
2. Pakar Management Sdn Bhd (Pakar, 1994)

3. The Environmental Impact Assessment for Putrajaya (UPM, 1995)
4. Minconsult/HGM, November 1995

(2) The summary of the water quality data is shown in Table 2.6.1. The sampling locations within the respective sub-catchment, that is the Upper West, Upper North, Upper East, Bisa, Central and Lower Sg Chuau are shown in Figure 2.6.1.

Table 2.6.1 Water Quality in Sg Chuau.

a. Physico-chemical Characteristics of the Lower Sg Chuau (Minconsult/HGM)

	JPK (April 1994)	Pakar (Date unknow)	UPM (June 1995)	Minconsult/ HGM (Nov 1995)
Station No	33	2	12	10
Temp ^oC	-	27.3	28.0	27.5
TDS, mg/l	20	805	42	-
Cond, uS/cm	36	-	60	46
Turbidity,NTU	11	110	27	35
TSS,mg/l	74	275	20	14
DO, mg/l	-	7.2	6.8	7.0
BOD, mg/l	-	13.5	1.0	1.0
COD, mg/l	-	29.0	3	<1
pH	6.7	6.4	6.6	6.8
Alkalinity,mg/l	-	-	-	12.3
Hardness, mg/l	12.0	-	-	13.8

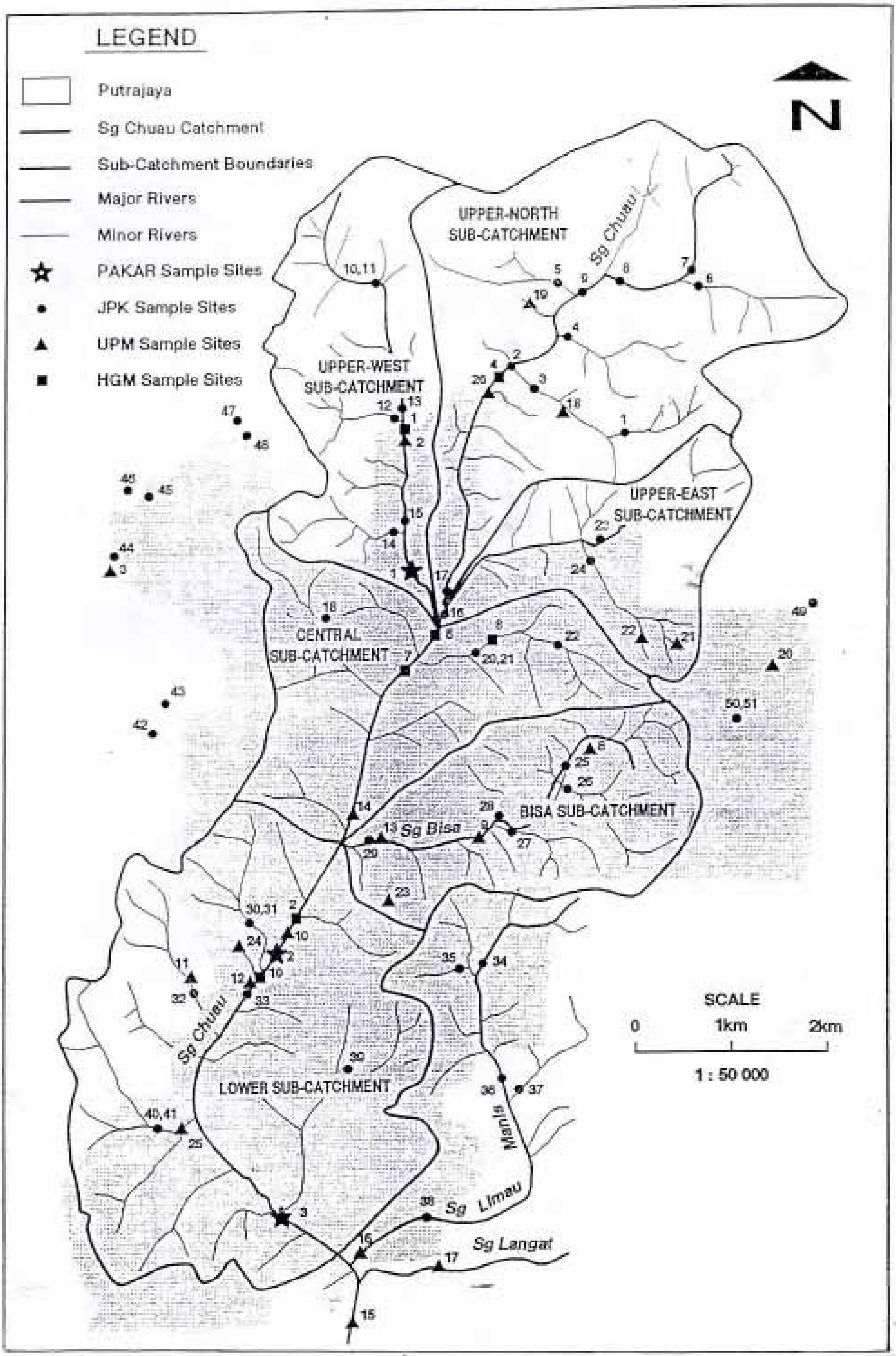


Figure 2.6.1: Location of Water Quality Sampling Sites (Kota Bistari, 1996)

b. Mean Ionic Composition of Catchment Stream Waters (Source: JPK, 1994)

Ion	**Mean concentration (ppm)**
Ca	3.39
Mg	0.70
Na	1.49
K	1.05
CO_3	1.02
HCO_3	17.65
F	0.5
Cl	2.06
SO_4	3.13

c. Mean Dissolved Oxygen, BOD and COD Concentrations and Ranges Obtained Over the Project Area.

	DOE class IIB	Minconsult/HGM (1995)	Previous other studies
DO, mg/l	507	6.4(5.0-7.1)	1.1-7.6
BOD, mg/l	3	1.5(0.8-3.0)	0.2-15.5
COD, mg/l	25	11.0(<1-18)	1.0-53.0

d. Bacteriological Characteristics of Sg Chuau Obtained Over the Project Area

	DOE class IIB	Minconsult/HGM(1995)	Pakar(1994)
Feacal coliform, count/100ml	100	17,000-160,000	-
Total coliform, count/100ml	5000	17,000-180,000	140,000-150,000

e. Metal Concentrations in Water and Sediment Samples in Relation to Selected Standards and Previous Data

	Water, mg/l		Sediment, mg/kg	
Metal	Minconsult/HGM (1995)	Previous studies	Minconsult/ HGM(1995)	Previous studies
As	<0.001-0.007	<0.005-0.03	<0.1- 32	10- 200
Al	-	<0.1-0.3	-	-
Fe	0.31-3.79	<0.1-0.3	0.59	0.1- 7.6
Mn	-	<0.1-0.3	1.95	3- 254
Cu	<0.01	<0.1	<1- 8.93	1- 51
Pb	0.05-0.15	<0.1	<5- 24.94	1- 40
Zn	<0.07-<0.02	<0.1-0.2	1.69- 31.18	3- 96
Co	-	<0.1	-	1- 5
Mo	-	<0.1	-	0.1- 9.4
Ni	<0.02	<0.1	<2	1- 16
Cd	<0.02	<0.01	<2	1
Sn	-	<0.01	-	10- 40
Ba	-	<0.1	-	16- 87
Se	-	<0.005	-	-
B	-	<5	-	-
Cr	<0.03-0.05	<0.01	<3- 17.87	3- 137
Ti	-	-	470- 8580	-
Hg	<0.001	0.00002-0.00012	0.5- 1.49	0.02- 0.8

B. Pre-Construction Information

(1) Nine monitoring stations were established by the PJH consultant (Angkasa GHD) prior to construction of the wetlands and lake. The locations of the nine stations are indicated in Figure 2.6.2 and described in Table 2.6.2. Monthly sampling was carried out for a period of six months from December 1996 to May 1997. The analysis was carried out by Core Laboratories. A summary of the

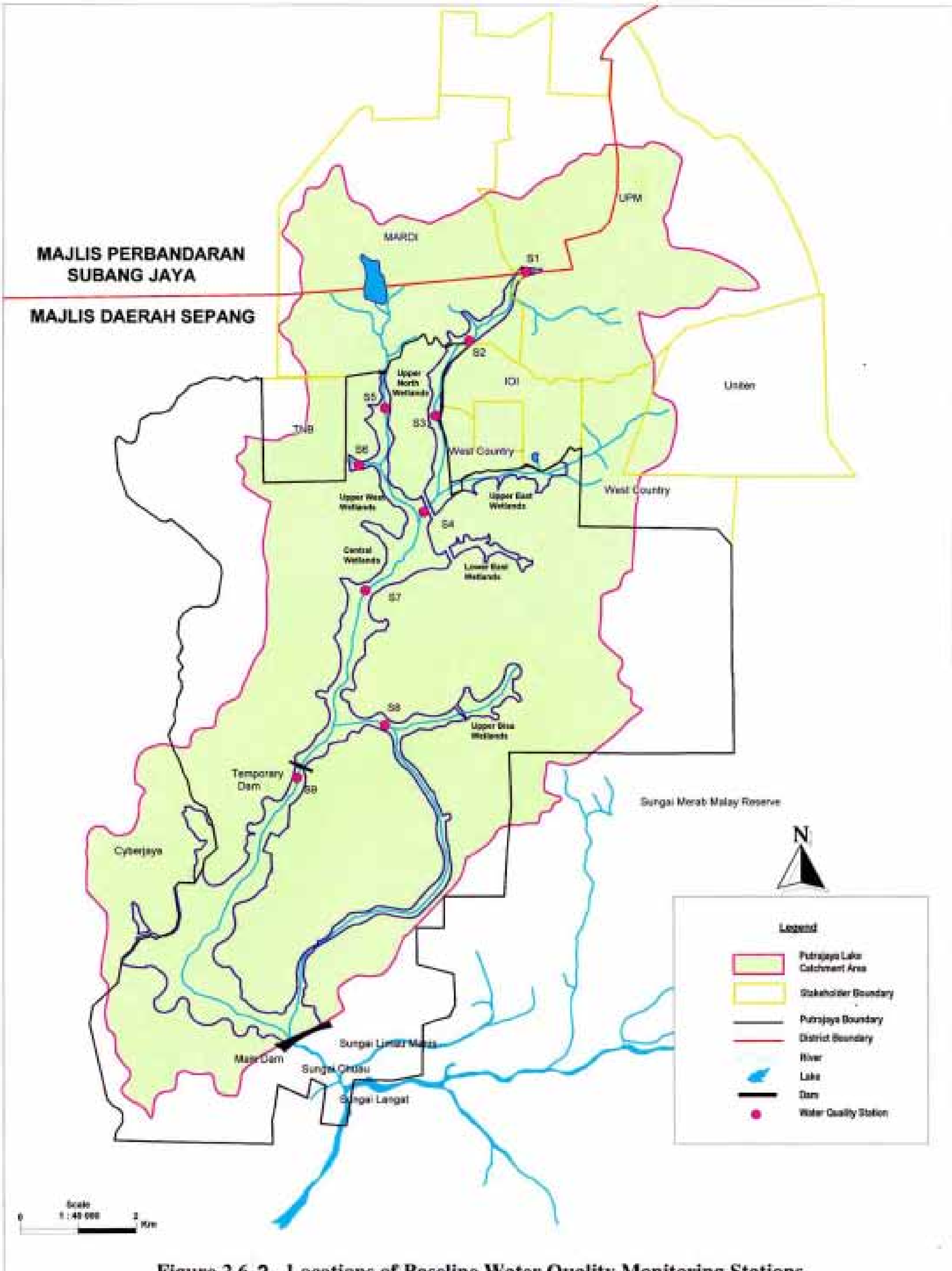


Figure 2.6.2 Locations of Baseline Water Quality Monitoring Stations

results of the water quality monitoring at the nine stations is given in Table 2.6.3.

(2) The results indicate that :-

(i) the water from the upper Sg Chuau catchment of Upper-North and from the Sg Bisa catchment contains high Total Phosphorous but that most of the phosphorus is in the particulate form. The concentration from the Sg. Kuyoh catchment, or the Upper-West, is lower.

(ii) The Total Nitrogen from both catchments, however, exceeds the guidelines.

(iii) The coliform counts from all catchments exceed the guidelines.

(iv) Several heavy metals exceed the guideline levels. A high Total Iron and Manganese concentration is not unusual but the high Total Mercury is of concern.

(v) Insecticide and herbicide concentrations were all low.

C. Commissioning Stage

(1) The wetlands is still in the commissioning stage. Monitoring is carried out by Putrajaya Holdings Sdn. Bhd.′s subcontractor Marimas) twice monthly at each wetland cell from 1997. A sample of the data for the month of April 1999 is given in Table 2.6.4. The data are compared to the Baseline Monitoring Stations as listed in Table 2.6.2.

(2) These indicate that nutrient input is negligible but the amounts of coliform again exceeded the proposed Putrajaya Ambient Lake Quality Standards (Table 2.6.5). Some values also exceed the value of 2000 counts/100 ml which may be regarded as the upper limit for health considerations of recreational use without body contact. Due to the low concentration analysed, the results for

several parameters are only indicated to be less than a certain value. Thus, the wetland efficiency could not be assessed especially for phosphorus.

Table 2.6.2 Water Quality Baseline Monitoring Stations

Station No.	**Description**
S1	Sg Chuau northeast tributary
S2	Inlet to Upper North Wetland
S3	Stormwater outlet at IOI Palm Golf Course
S4	Upper East Wetland, downstream of IOI Palm Golf Course
S5	Inlet to Upper West Wetland
S6	TNB Power Station stormwater drain outlet
S7	Secondary Lake Weir
S8	Sg Bisa
S9	Temporary Dam, near JPS gauging station

Table 2.6.3 Summary of Water Quality Monitoring Results at the Pre-construction Stage (from Quek, 1997)

Parameter	**S1** UN	**S2** UN	**S3** UN	**S4** UE	**S5** UW	**S6** UW	**S7** CW	**S8** UB	**S9** TD
Temperature, °C	28-30.2	27-31	27-34	26-34	29-32.4	27-29	27-32.8	26-32	28-32.3
Conductivity	68-100	62-76	64-80	22-29	28-42	21-27	43-55	29-37	44-52
Ph	6.6-7.1	6.5-7.4	6.5-6.9	5.98-6.8	6.2-7.1	5.6-6.9	6.4-7.37	5.68-7.0	6.12-7.3
Colour, PtCo	2-21	7-20	7-44.7	4-39	6-29	1-9	14-82	6-21	13-42
Turbidity, FTU	7.8-251	10.47-60.0	9.36-60.0	5.42-39.1	0.19-41.2	0.18-24.83	8.2-102	10.4-67	25.36-193
TSS, mg/l	6-101	6-68	7-46	4-23	4-140	4-33	10-75	4-94	11-146
Total P, mg/l	0.03-0.36	0.01-0.19	0.01-0.29	0.01-0.15	0.01-0.29	0.01-0.15	0.01-0.18	0.02-0.13	0.01-0.12
Filterable P, mg/l	0.1-0.18	0.1-0.18	0.1-0.18	0.1-0.18	0.1-0.18	0.1-0.18	0.1-0.18	0.1-0.18	0.1-0.18
Total N, mg/l	4.04-9.41	3.54-8.79	3.49-4.57	1.68-2.86	1.93-3.12	1.1-2.13	2.13-3.42	1.45-2.79	2.12-3.54
Total oxidised N, mg/l	1.72-2.88	1.72-3.65	1.72-3.8	1.08-1.63	0.93-1.93	0.66-1.2	1.4-2.23	0.69-1.38	1.44-2.1
Ammonia N, mg/l	0.12-1.59	0.16-6.24	0.09-0.55	0.04-0.18	0.17-0.49	0.01-0.2	0.16-0.47	0.21-0.37	0.14-0.58
BOD5, mg/l	0.85-7.16	0.54-3.48	0.31-6.27	0.74-4.82	0.02-14.7	0.47-2.23	0.81-4.78	0.45-4.21	0.08-4.3
COD, mg/l	6-24	1-9	1-24	1-7	1-41	1-5	1-10	1-10	1-9
DO, ppm	3.81-6.9	4.13-6.8	4.66-7.52	5.44-6.8	3.74-6.9	4.25-7.0	5.8-6.8	5.66-7.05	6.25-6.9
Total Coliform, MPN/100ml	16000-90000	3000-30000	16000-90000	9000-90000	3000-90000	70-17000	5000-50000	16000-18000	16000-50000
Faecal Coliform,	700-3000	700-1600	210-1600	220-900	270-9000	2-230	1300-	260-800	500-2400

Parameter	**S1** UN	**S2** UN	**S3** UN	**S4** UE	**S5** UW	**S6** UW	**S7** CW	**S8** UB	**S9** TD
MPN/100ml	0	0	0				3000		
Total Iron, mg/l	0.66-5.74	0.88-1.69	0.76-2.21	0.34-2.27	0.48-10.92	0.18-1.58	0.54-3.48	0.91-3.29	0.6-4.66
Total Mn, mg/l	0.07-0.17	0.08-0.13	0.09-0.19	0.05-0.13	0.02-0.07	0.11-0.18	0.09-0.22	0.05-0.18	0.09-0.36
Total Zn, mg/l	0.002-0.06	0.02-0.08	0.002-0.09	0.03-0.06	0.002-0.06	0.002-0.19	0.01-0.06	0.002-0.28	0.002-0.1
Total Pb, mg/l	0.03-0.04	<0.03-0.03	<0.03	<0.03	0.03-0.07	0.03-0.05	<0.03	<0.03	<0.03
Total Hg, mg/l	0.001-0.007	0.001-0.004	0.001-0.005	0.001-0.005	0.001	0.001	0.001-0.04	0.001-0.004	0.001-0.008
Total Cr, mg/l	0.02-0.06	0.02-0.04	<0.02	<0.02	0.02-0.1	0.02-0.06	0.02-0.06	<0.02	<0.02
Insecticides	<	<	<	<	<	<	<	<	<
Herbicides	<	<	<	<	<	<	<	<	<

> : exceeds the Class II Guidelines for water quality; < : less than; = : equivalent to;
UN : Upper-North; UW : Upper-West; UE : Upper-East; UB : Upper-Bisa; CW : Central Weir;
TD : Temporary Dam

Table 2.6.4 Summary of Wetland Water Quality in May, 1999 (Source: Putrajaya Holdings).

1. Upper-West

Parameter	Unit	Range	Mean	Core Lab S5	Core Lab S6	Class IIB
pH	-	4.8- 6.7	5.9	6.2	5.6	6.5- 9.0
Temp	^{o}C	31.4- 37.0	33.4	-	-	-
TSS	mg/l	12.0- 46.0	22.4	43.0	15.0	50.0
Cond.	µmhos/ cm	44.0- 100.0	68.3	-	-	-
Ammonia	mg/l	0.12- 0.25	0.19	0.3	0.2	0.3
Nitrate	mg/l	0.26- 3.67	1.27	1.9	1.1	-
Phosphorus	mg/l	<0.01	<0.01	0.01	<0.01	-
Mercury	mg/l	<0.001	<0.001	<0.001	<0.001	-
Lead	mg/l	<0.006	<0.006	0.07	<0.03	-
DO	mg/l	3.8- 6.6	5.8	7.3	7.4	4.5- 6.4
COD	mg/l	<1.0- 27.0	<8.4	4.0	2.0	25.0
F.coli	MPN/ 100ml	1000- 5000	2970	300	2	400
BOD	mg/l	<2.0- 2.3	<2.0	<0.8	<0.5	25.0

2. Upper North

Parameter	Unit	Range	Mean	Core Lab S1	Core Lab S2	Core Lab S3	Class IIB
pH	-	5.6-6.5	6.2	7.0	7.4	6.5	6.5- 9.0
Temp	^{o}C	30.4-32.8	31.6	-	-	-	-
TSS	mg/l	7.0-25.0	16.4	6.0	23.0	24.0	50.0
Cond.	µmhos/cm	54.0-86.0	76.5	-	-	-	-
Ammonia	mg/l	0.11-0.76	0.30	0.4	0.3	0.4	0.3
Nitrate	mg/l	0.48-5.10	2.01	2.3	2.2	2.1	0.3
Phosphorus	mg/l	<0.01	<0.01	0.03	<0.01	<0.01	-
Mercury	mg/l	<0.001	<0.001	<0.001	0.002	<0.001	-
Lead	mg/l	<0.006	<0.006	0.03	0.03	<0.03	-
DO	mg/l	4.7-6.1	5.4	7.3	7.2	7.3	4.5- 6.4
COD	mg/l	<1.0-37.0	<11.9	6.0	6.0	24.0	25.0
F.coli	MPN/100ml	1300-45500	13670	5000	700	500	400
BOD	mg/l	<2.0-2.3	<2.1	<0.9	<0.8	<0.3	25.0

3. Upper East

Parameter	Unit	Range	Mean	Core Lab S4	Class IIB
pH	-	5.7- 6.5	6.1	6.0	6.5-9.0
Temp	^oC	28.2- 31.2	30.4	-	-
TSS	mg/l	7.0- 16.0	11.8	21.0	50.0
Cond.	µmhos/cm	24.0- 52.0	40.5	-	-
Ammonia	mg/l	0.18- 0.28	0.22	0.1	0.3
Nitrate	mg/l	0.66- 1.57	0.99	1.4	-
Phosphorus	mg/l	<0.01	<0.01	<0.01	-
Mercury	mg/l	<0.001	<0.001	<0.001	-
Lead	mg/l	<0.006	<0.006	<0.03	-
DO	mg/l	5.6- 6.4	5.9	7.2	4.5-6.4
COD	mg/l	6.0- 30.0	18.8	7.0	25.0
F.coli	MPN/100 ml	2900-5900	4750	500	400c
BOD	mg/l	<2.0- 2.2	<2.1	<0.7	25.0

4. Lower East

Parameter	Unit	Range	Mean	Core Lab S7	Class IIB
pH	-	6.1- 6.3	6.2	6.5	6.5-9.0
Temp	^oC	29.4- 32.2	31.1	-	-
TSS	mg/l	15.0- 54.0	29.0	14.0	50.0
Cond.	µmhos/cm	98.0- 99.0	98.7	-	-
Ammonia	mg/l	0.24- 0.41	0.31	0.3	0.3
Nitrate	mg/l	0.73- 1.98	1.28	2.0	-
Phosphorus	mg/l	<0.01	<0.01	<0.01	-
Mercury	mg/l	<0.001	<0.001	<0.001	-

Lead	mg/l	<0.006	<0.006	<0.03	-
DO	mg/l	5.1- 6.7	6.1	7.2	4.5-6.4
COD	mg/l	<1.0- 11.0	<7.0	3.0	25.0
F.coli	MPN/ 100ml	500-900	666.7	500	400c
BOD	mg/l	<2.0- 2.0	<2.0	<0.8	25.0

5. Upper Bisa

Parameter	**Unit**	**Range**	**Mean**	**Core Lab S8**	**Class IIB**
pH	-	6.8-7.3	7.1	5.7	6.5-9.0
Temp	^{o}C	30.4-31.3	31.0	-	-
TSS	mg/l	12.0-18.0	14.3	14.0	50.0
Cond.	µmhos/cm	120.0-169.0	148.0	-	-
Ammonia	mg/l	0.12-0.35	0.25	0.3	0.3
Nitrate	mg/l	0.56-2.64	1.77	1.2	-
Phosphorus	mg/l	<0.01	<0.01	0.03	-
Mercury	mg/l	<0.001	<0.001	<0.001	-
Lead	mg/l	<0.006	<0.006	<0.03	-
DO	mg/l	6.0-7.4	6.5	7.0	4.5-6.4
COD	mg/l	<1.0-12.0	<5.7	10.0	25.0
F.coli	MPN/ 100ml	900-5300	3066.7	500	400c
BOD	mg/l	<2.0-2.8	<2.3	<0.5	25.0

6. Central Wetland

Parameter	Unit	Range	Mean	Core Lab S7	Class IIB
pH	-	6.2-6.7	6.6	6.5	6.5-9.0
Temp	^{o}C	30.8-31.9	31.5	-	-
TSS	mg/l	11.0-21.0	17.0	14.0	50.0
Cond.	µmhos/cm	73.0-76.0	75.0	-	-
Ammonia	mg/l	0.09-0.10	0.10	0.3	0.3
Nitrate	mg/l	0.35-3.72	1.21	2.0	-
Phosphorus	mg/l	<0.01	<0.01	<0.001	-
Mercury	mg/l	<0.001	<0.001	<0.03	-
Lead	mg/l	<0.006	<0.006	<0.03	-
DO	mg/l	6.0-6.5	6.3	7.2	4.5-6.4
COD	mg/l	<1.0-11.0	<6.8	3.0	25.0
F.coli	MPN/ 100ml	100-800	525	3000	400c
BOD	mg/l	<2.0	<2.0	<0.8	25.0

7. Primary Lake

Parameter	Unit	Range	Mean	Core Lab S7	Class IIB
pH	-	6.6-7.2	7.0	6.5	6.5-9.0
Temp	^{o}C	30.9-31.9	31.4	-	-
TSS	mg/l	7.0-18.0	13.3	14.0	50.0
Cond.	µmhos/cm	82.0-115.0	99.3	-	-
Ammonia	mg/l	0.07-0.16	0.11	0.3	0.3
Nitrate	mg/l	0.42-0.73	0.58	2.0	-
Phosphorus	mg/l	<0.01	<0.01	<0.001	-
Mercury	mg/l	<0.001	<0.001	<0.001	-
Lead	mg/l	<0.006	<0.006	<0.03	-
DO	mg/l	6.1-7.4	6.7	7.2	4.5-6.4
COD	mg/l	<1.0-16.0	<4.8	3.0	25.0
F.coli	MPN/ 100ml	800-3700	1900	3000	400c
BOD	mg/l	<2.0	<2.0	<0.8	25.0

Table 2.6.5 Putrajaya Ambient Lake Water Quality

Lake Water Quality Parameter	**Unit**	**Putrajaya Ambient Lake Water Quality Standards**
Aluminium	mg/l	<0.05 if pH<6.5* <0.1 if pH>6.5
Ammoniacal Nitrogen	mg/l	0.3
Ammonia	mg/l	0.02-0.03
Arsenic	mg/l	0.05
Antimony	mg/l	0.03
Barium	mg/l	1
Beryllium	mg/l	0.004
Boron	mg/l	1
Cadmium	mg/l	0.002
Free Chlorine (revised)	**mg/l**	**0.02***
Chromium, Total	mg/l	0.05
Copper	mg/l	0.02
Cyanide	mg/l	0.02
Flourine	mg/l	1.5
Iron	mg/l	1
Lead	mg/l	0.05
Manganese	mg/l	0.1
Mercury	mg/l	0.0001
Nickel	mg/l	0.02
Nitrate (NO3-N)	mg/l	7
Nitrite (NO2-N)	mg/l	0.04
Total Phosphorus	mg/l	0.05*
Silica	mg/l	50
Selenium	mg/l	0.01
Silver	mg/l	0.05
Sulphur	mg/l	0.05
Sulphate	mg/l	250
Zinc	mg/l	5
BOD	mg/l	3
COD	mg/l	25
Colour	TUC	150
Conductivity	uS/cm	1000
Salinity	ppt	1
Total suspended solids	mg/l	50
Turbidity	NTU	50
Transparency (Secchi)	m	0.6*
Hardness	mg/l	250
Taste		No Objectionable Taste
Dissolved Oxygen	mg/l	5 – 7

Lake Water Quality Parameter	Unit	Putrajaya Ambient Lake Water Quality Standards
Odour		No Objectionable Odour
pH		6.5 - 9.0
Temperature	^{o}C	Normal$\pm$2
Oil & Grease	mg/l	1.5
Chlorophyll a	ug/l	0.7*
Floatables		No Visible Floatables
Microbiological Constituents		
Feacal coliform (clarification)	**counts/100 ml**	**100*** **
Total coliform	counts/100ml	5000
Salmonella	counts/l	0
Enteroviruses	PFU/l	0
Radioactivity		
Gross-alpha	Bq/l	0.1
Gross-Beta	Bq/l	1
Radium-226	Bq/l	<0.1
Strontium-90	Bq/l	<1
Organics		
Carbon Chloroform extract	ug/l	500
MBAS/BAS	ug/l	500
Oil & Grease (mineral)	ug/l	40;NF
Oil & Grease (emulsified edible)	ug/l	7000;NF
PCB	ug/l	0.1
Phenol	ug/l	10
Aldrin/Dieldrin	ug/l	0.02
BHC	ug/l	2
Chlordane	ug/l	0.08
t-DDT	ug/l	0.1
Endosulfan	ug/l	10
Heptachlor/Epoxide	ug/l	0.05
Lindane	ug/l	2
2,4-D	ug/l	70
2,4,5-T	ug/l	10
2,4,5-TP	ug/l	4
Paraquat	ug/l	10

* - addition to Class II

** - 24 hour average (based on Class III)

*** - geometric mean of minimum of 5 samples in a 30-day period

2.6.2.2 Study Data

(1) For the calibration of the water quality in this study, monitoring of the inflow water quality and the water quality has been carried out by UPM.

(2) There are three different monitoring data targets. One set of data is for model calibration purpose The monitored data are shown in Appendix 2.1. The monitored water quality is at the top and the last cell of each wetlands for this purpose.

(3) The second target of the data collection is the water quality at each cell of the wetland to assess each cell removal efficiency (see Appendix 2.2).

(4) The third data target is the water quality in stream flows in UPM and MARDI under heavy pollutant load (see Appendix 2.3). Upper Bisa Wetland was not monitored as it was still under construction at the time of water quality monitoring by the UPM team.

(5) The pattern of the monitored water quality between the top cell and last cell of each wetlands is not simple; the parameter value can be reduced or increased. This effect may be due to the effect of lateral inflow from runoff or the resuspension of sediment-attached pollutants.

(6) The water quality along the wetlands fluctuates between cells. It could be reduced or increased from the previous cell. Similarly, as was discussed for the data in Table 2.6.6, this effect could be due to lateral inflow of runoff or resuspension of sediment-attached pollutants in the cells.

(7) Along the reed-lined streams in UPM and MARDI, removal of Total Phosphorus does occur with distance. This removal is primarily of the reactive dissolved phosphorus form, not the particulate. For other parameters the pattern is not distinct with some parameters showing increase and decrease along the distance. Again this may be due to lateral inputs from runoff. Turbidity in both cases reduce substantially, thus pollutant inflow must be of aqueous source such as interflow or surface runoff.

(8) From the monitored data in Appendix 2.1, the range of water quality at the dam can be summarised as in Table 2.6.6.

Table 2.6.6 Range of Water Quality at the Dam

	Range at the Dam, mg/l
DO	2.8- 4.0
BOD	0.11- 1.89
NO3	0.5- 2.9
TP	0.04- 0.57
Turbidity, NTU	2.0- 26.68
Ecoli, count/100ml	0- 4000
Tcoli, count/100ml	0- 5000

2.6.3 Water Quality Modelling

Water quality modelling is conducted for the Putrajaya Lake System. The software programme , MIKE 11 is used to assess the water quality for the proposed and likely future land-use scenarios in the catchment and the hydrological regimes arising from them.

2.6.3.1 Review of Previous Model

(1) Water quality modelling had been conducted in the previous studies by Perunding Kota Bistari in its Water Quality Control and Management Study on Putrajaya Lake Development (1996) and Angkasa GHD Engineers in its Putrajaya Lake Phase 1 Concept Design Report Wetland Component (1996). The two studies used slightly different data and information. The data presented here are from their study reports.

A. Water Quality Control and Management Study (Perunding Kota Bistari, 1996)

(2) In this report, Minconsult/HGM had set up a simple water quality model to estimate the equilibrium concentrations of suspended solids, nutrients and BOD/COD in the lake

on the basis of the estimated mean annual flow rates from each sub-catchment and the design input pollutant concentrations as shown in Table 2.6.7 and Table 2.6.9. The data given in Table 2.6.7 differs from that in another section of the report on existing river flow as shown in Table 2.6.8.

Table 2.6.7 Mean Annual flow rates from Contributing Sub-catchments (from Table 4.1, Perunding Kota Bistari)

Sub-catchment	Upper-west	Upper-north	Upper-east	Upper-Bisa	Lower-east	Central	Lower Chuau	Total
Net Area, km^2	6.2	12.4	4.2	4.0	1.7	5.5	10.0	44.0
Mean Annual Inflow, m^3/s	0.33	0.67	0.23	0.22	0.09	0.30	0.54	2.38

Table 2.6.8 Mean Annual flow rates from Contributing Sub-catchments (from Table 3.6, Perunding Kota Bistari)

Sub-catchment	Upper-west	Upper-north	Upper-east	Upper-Bisa	Lower-east	Central	Lower Chuau	Total
Net Area, km^2	6.2	12.4	4.2	5.9	-	7.1	14.7	50.5
Total Annual Inflow, m^3/s	0.16	0.33	0.11	0.16	-	0.19	0.39	1.33

Table 2.6.9 Modelled Pollutant Input Concentrations

	Design input concentrations from direct drainage, mg/l	Assumed pollutant removal efficiency in Primary Wetlands	Design input concentrations via Primary Wetlands, mg/l
TSS	150	90%	15
Total phosphorus	0.5	60%	0.2
Total nitrogen	0.5	90%	0.05
BOD	10.0	90%	1.0
COD	50	90%	5.0

(3) In the model, the water quality of Putrajaya Lake had been estimated by assuming the lake was a well mixed system with constituent concentrations approximately uniform within the lake but subject to first-order decay.

(4) The modelled equilibrium concentrations of total suspended solids, nutrients and BOD/COD in the lake are presented in Table 2.6.10.

The report concluded that an inflow phosphorus concentration of 0.1 mg/l would be the acceptable upper limit of mean TP concentration in the catchment.

Table 2.6.10 Equilibrium Contaminant Concentrations in the Putrajaya Lake

Contaminant	Equilibrium concentration, mg/l
TSS	16
Total nitrogen	0.14
Total phosphorus	0.20
BOD	0.8
COD	5.6

B. Putrajaya Lake Phase 1 Concept Design Report Wetland Component (Angkasa GHD Engineers, 1996)

(5) The AQUALM model was chosen to model water quality in the wetlands and the primary lake. AQUALM is an integrated rainfall runoff and water quality model which simulates long term pollutant export and retention using a daily time step. The model requires rainfall, evaporation and catchment data as well as estimates of export rates from various land use types. The pollutant selected for the analysis were total phosphorus, total nitrogen and suspended solids.

(6) The model uses pollutant retention curves (based on hydraulic residence time) to estimate daily pollutant removal rates. Eutrophication potential is assessed using Vollenweider analysis - assuming phosphorus is the limiting nutrient. The values of bio-available phosphorus was taken to be 0.3 for urban areas, 0.1 for rural areas and 0.9 for sewage sources for this study's model.

(7) The pollutant retention curves were derived from data sourced from Canberra (Australia) wetlands. It was considered that adoption of these curves would be a conservative approach to estimating pollutant retention capabilities of the Putrajaya Wetlands because of increased macrophyte cover and increased flood retention storage.

(8) Initial model parameters of water balance were based on calibration of two urban catchments in Brisbane (Australia), later modified to reflect the runoff volumes estimated by DID.

(9) The loading rates for pollutant export loads adopted for established urban conditions were based on calibrated loads from two established urban catchments located in Brisbane, Australia.

(10) To simplify the model, cells for each wetlands were modeled as a single cell by referencing each cell's storage and area values to the cell's normal water level.

(11) The model scheme used is shown in Figure 2.6.3 and the total phosphorus loads with and without catchment treatment as shown in Figure 2.6.4 to Figure 2.6.5.

(12) The Vollenweider analysis showed that the maximum tolerable average loading rates is approximately 4 $gP/m^2/y$.The maximum desirable loading rate is approximately 1.5 $g P/m^2/y$. Only the Phase 1 lake (to the temporary dam) is less than this value.

(13) All wetlands reduced phosphorus concentration by about 70% except for the Bisa wetland which was modeled as a sedimentation system rather than as a macrophyte system.

(14) This analysis showed that under normal urban loadings, the target 0.05 mg/l phosphorus influent concentration into the Primary Lake is not achieved. The calculated influent concentration was 0.13 mg/l.This implies that average influent concentration into the wetlands must be reduced from 0.4 mg/l to 0.15 mg/l. Likewise runoff concentrations from non-treated areas must be of the same quality.

(15) Modelling was only carried out for Phase 1A of the Lake. Most of the inputs into Phase 2 of the Lake would not be treated by wetlands. Based on this Angkasa-GHD concluded that the maximum permissible average concentration would likely be lower than 0.15 mg/l and may possibly be about 0.1 mg/l. This concurs with the Kota Bistari model report.

(16) **This implies that influent entering through the wetlands should be of at most 0.15 mg/l of Total Phosphorus but that the influent entering directly into the Lake, from within Putrajaya and Cyberjaya, must be lower than 0.15 mg/l of Total Phosphorus.**

2.6.3.2 MIKE 11 Software

(1) MIKE 11 is a professional engineering software package for the simulation of flows, water quality and sediment transport in estuaries, rivers, irrigation systems, channels and other water bodies. It is a dynamic, one-dimensional modelling tool for the

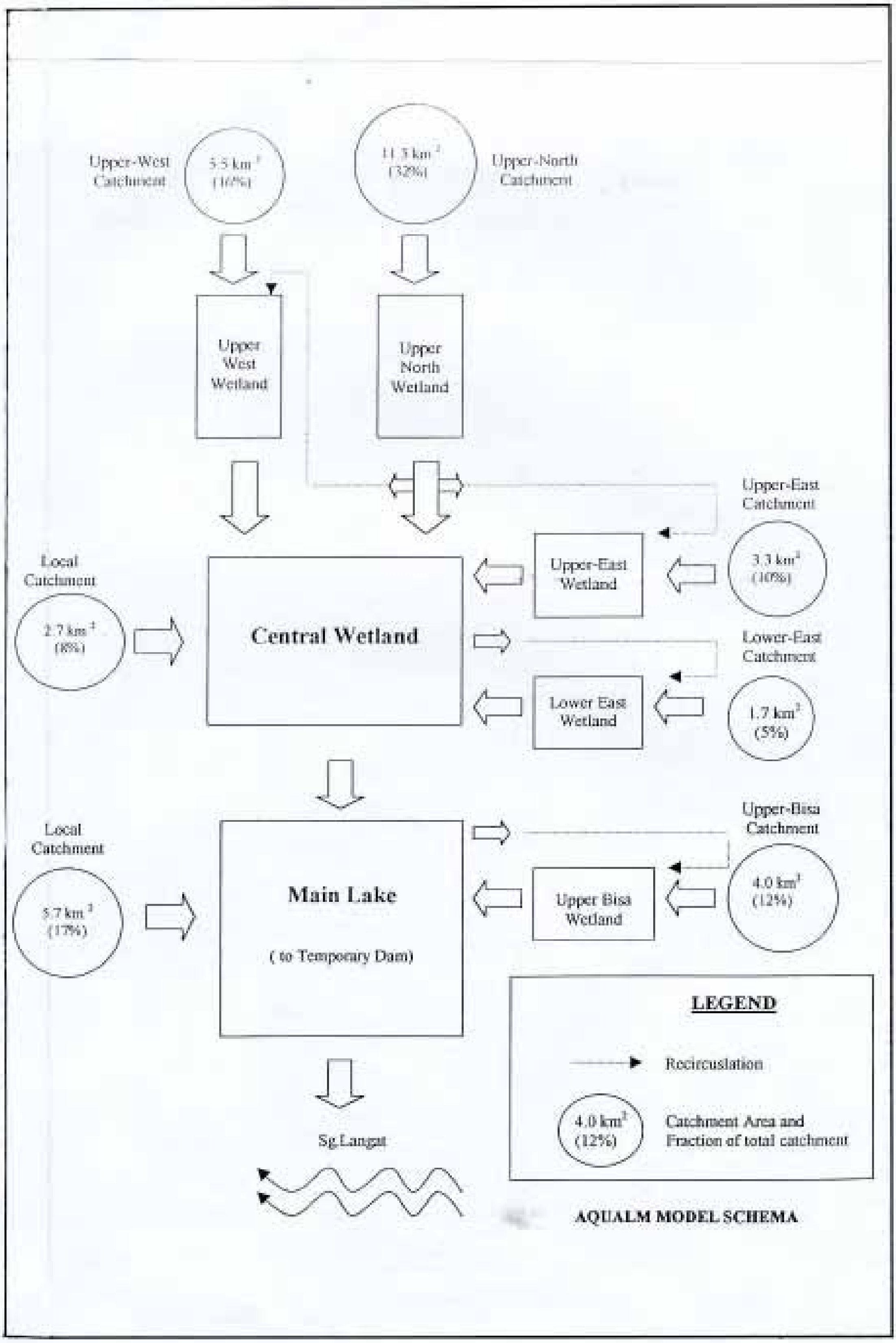
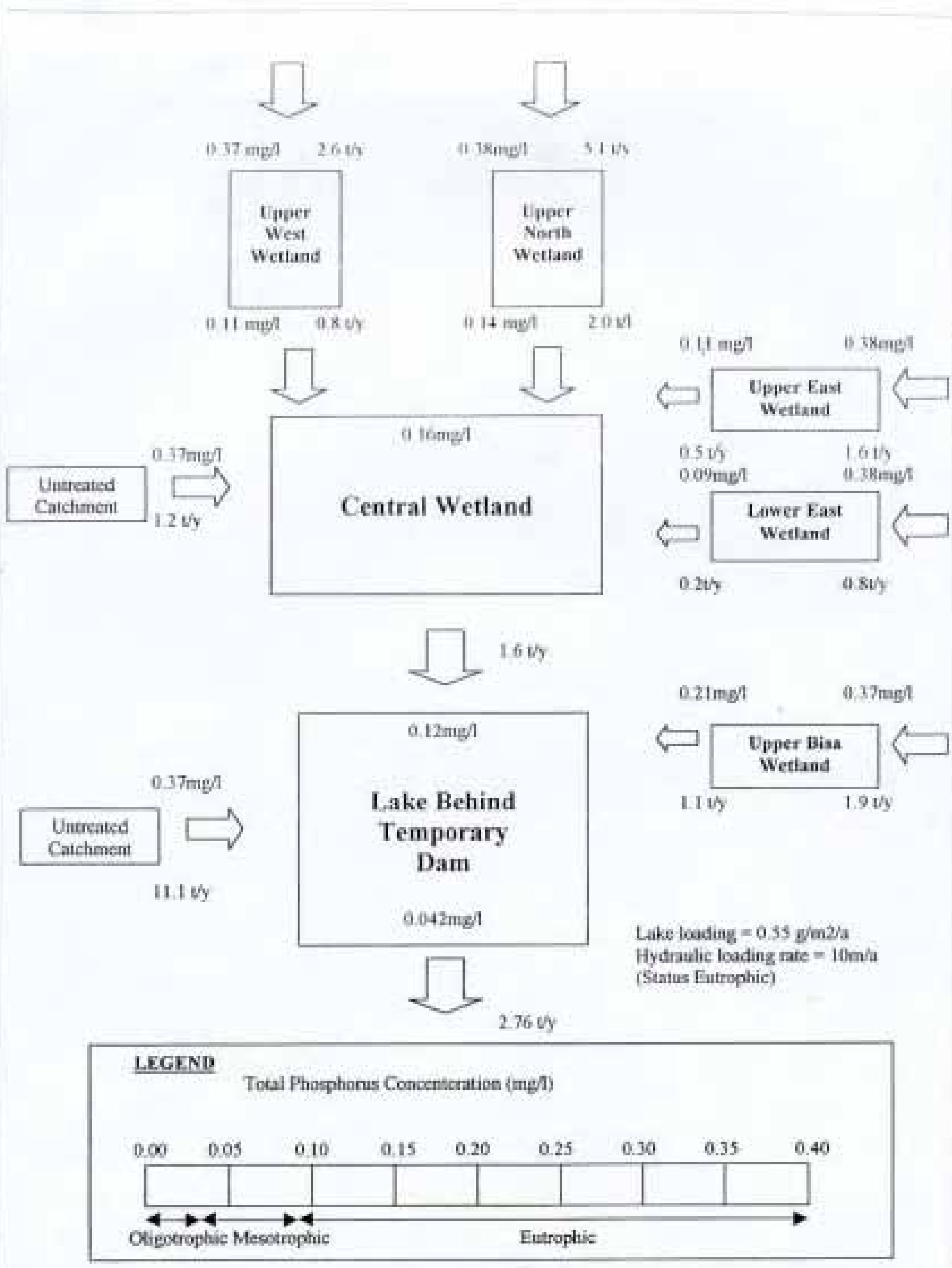


Figure 2.6.3: AQUALM Model Scheme



TOTAL PHOSPHORUS LOADS IN LAKE AND WETLANDS WITHOUT CATCHMENT TREAMENT

Figure 2.6.4: AQUALM Model Scheme - Total Phosphorus Loading in Lake and Wetlands Without Catchment Treatment

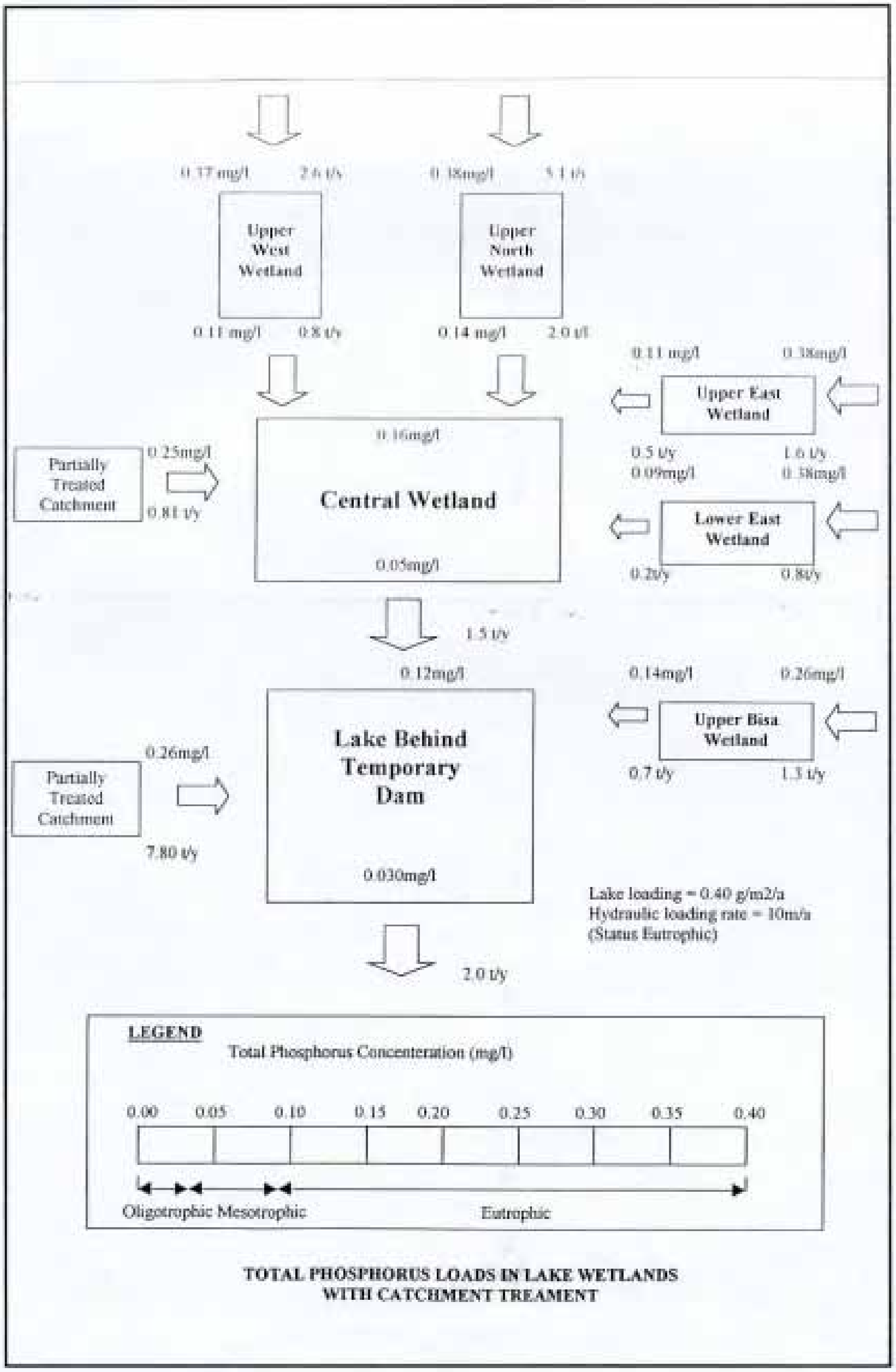


Figure 2.6.5: AQUALM Model Scheme - Total Phosphorus Loading in Lake and Wetlands With Catchment Treatment

design, management and operation of river and channel systems.

(2) The Hydrodynamics (HD), Advection-Dispersion (AD) and the Water Quality (WQ) modules were applied for assessment of the water quality in the Lake system.

(a) Hydrodynamic Module (HD)

(3) The HD module contains an implicit, finite difference computation of unsteady flows in rivers and estuaries. The formulations can be applied to branched and looped networks.

(4) The computational scheme is applicable to vertically homogeneous flow conditions ranging from steep river flows to tidally influenced estuaries. Both subcritical and supercritical flow can be described by means of a numerical scheme which adapts according to the local flow conditions.

(5) The complete non-linear equations of open channel flow (Saint Venant) can be solved numerically between all grid points at specified time intervals for given boundary conditions.

(6) Within the standard HD module advanced computational formulations enable flow over a variety of structures to be simulated :

- Broadcrested weirs
- culverts
- user-defined structures

(7) The HD module essentially calculates the hydraulic flow through the cross-sections and under the controls defined by the user.

(b) Advection Dispersion Module (AD)

(8) This module describes the flow of a mass through the hydraulic system predicted by the HD module. The AD module is based on the one-dimensional equation of conservation of mass of a dissolved or suspended material (eg salt or cohesive sediments). The behaviour of

conservative materials which decay linearly can be simulated. The module requires output from the hydrodynamic module, in space and time, of discharge and water level, cross-sectional area and hydraulic radius.

(9) The advection-dispersion equation is solved numerically using an implicit finite difference scheme which has negligible numerical dispersion. Concentration profiles with very steep fronts can be simulated accurately.

(c) Water Quality Module (WQ)

(10) A water quality module is coupled to the AD module and simulates the reaction processes of multi-compound systems including the degradation of organic matter, the photosynthesis and respiration of plants, nitrification and the exchange of oxygen with the atmosphere.

(11) The mass balance for the parameters involved are calculated for all grid points at all time steps using a rational extrapolation method in an integrated two-step procedure with the AD module.

(12) Using the MIKE 11 simulation, the variation and longitudinal profile of the mean water quality concentration at selected sections for the given hydrological regimes will be assessed for the study of the Catchment Development and Management Plan for Putrajaya Lake.

(13) The state variables that are used for the modelling include: Dissolved Oxygen, Temperature, Ammonia, Nitrate, BOD, Dissolved Phosphorus, Particulate Phosphorus. The processes involved Degradation of Organic Matter, Oxygen Processes, Temperature, Nitrification, Denitrification, Bottom/Sediment, Phosphorus Processes in the Water Pase, Phosphorus Pocesses at the Bttom, Ntrient Utake by Pants and Agae.

(14) The model is very applicable to general studies of effects of discharges of municipal and agricultural run-off.

2.6.3.3 Model Physical Setup

Information for the model programme was obtained from secondary data as provided by other consultants and Perbadanan Putrajaya**.**

1. The river networks, the longitudinal section, cross sections and the weir geometry were taken from the Putrajaya as-built plan and the Bulk Earthworks and Drainage plan.

2. Water quality data on each cell of the wetlands was provided by Putrajaya Holdings for preliminary assessment. The monthly sampling records were from May 1997 to May 1999. Time series data collection was carried out by Universiti Putra Malaysia. Some variations in phosphorus values were apparent and the use of the Putrajaya Holdings data is discontinued until an intercomparison of the data set is carried out.

(a) Model Setup

(1) The Putrajaya Wetlands and Lake Networks was setup with the data linking the Upper West wetland, Upper North wetland, Upper East wetland, Lower East wetland, Upper Bisa wetland, the Central wetland, the primary Lake and the looped secondary Lake as shown in Figure 2.6.6. The hydrological inputs are as explained in the Hydrological section.

(2) The whole network utilised the design normal water levels as determined by the weir's crest and the dam spillway level as shown in Table 2.6.11. The average volume of each wetlands at their normal water levels as compared to the survey volume in the as-built plan are in Table 2.6.12.

(3) The pollutant inputs into the networks will be subjected to the model's Water Quality processes as stated above. The water quality model requires input of a number of physical and biological parameters with temperature coefficient.

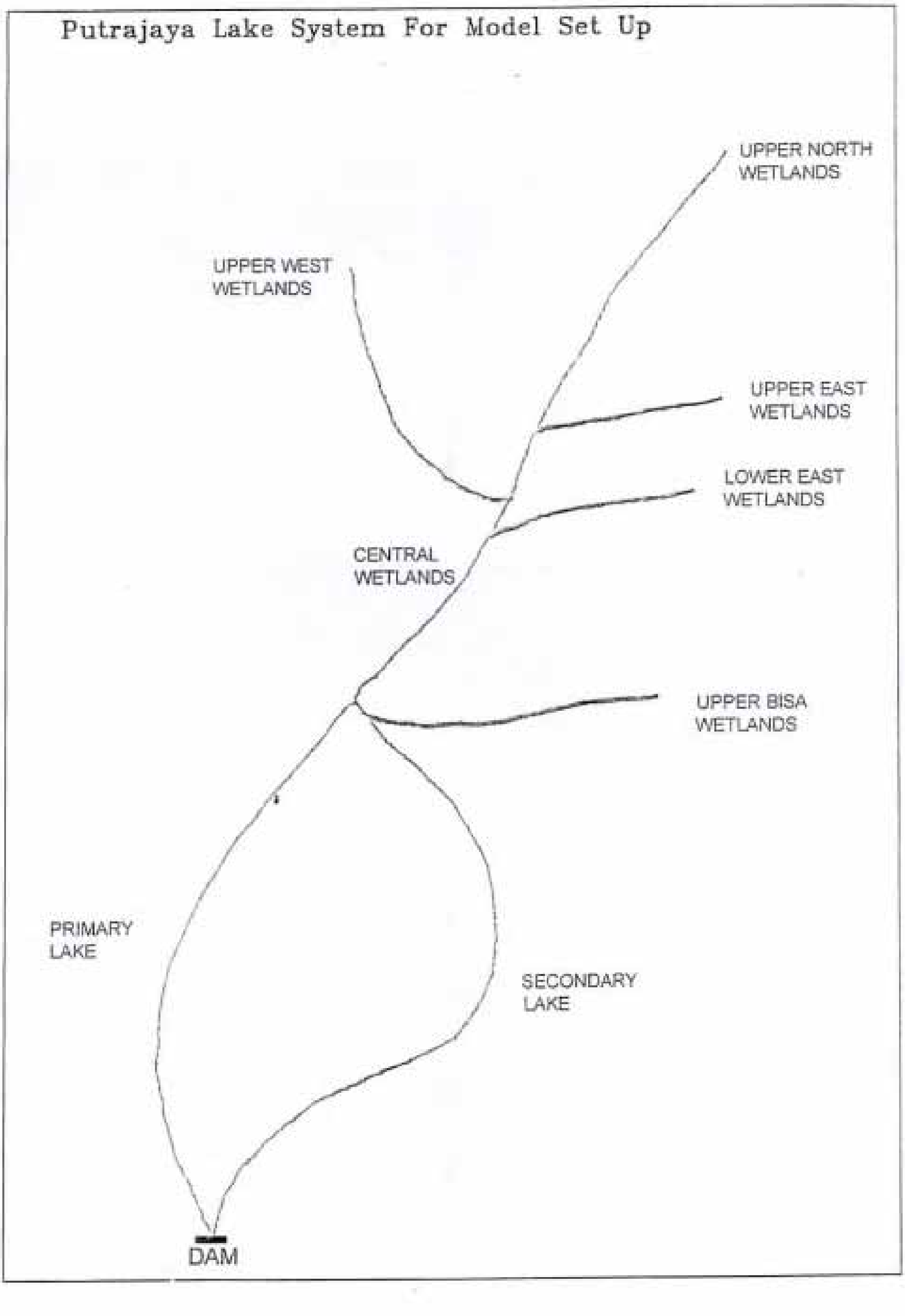


Figure 2.6.6 Putrajaya Wetlands and Lake Network

(b) Calibration

(1) For the calibration of the model, it is important that data on the time series of the observed water quality parameters be obtained. Thus, monitoring of the inflow water quality and the water quality at selected stations over a time period is being carried out by UPM to be used to calibrate the performance of the wetlands and lake.

Table 2.6.11 Location of Weirs in each Wetland Cells and its Normal Water Leval (NWL).

Cell No.		8	7	6	5	4	3	2	1
UW	Dis,m		612	790	1150	1340	1587	1960	2300
	NWL, m		29.0	28.5	27.75	27.0	26.0	25.25	24.5
UN	Dis,m	400	720	1520	1795	2110	2415	2745	3260
	NWL, m	30.0	29.0	28.0	27.5	26.75	26.0	25.0	24.5
UE	Dis,m						230	458	853
	NWL, m						30.0	29.0	28.5
LE	Dis,m							680	1355
	NWL, m							30.0	27.0
UB	Dis,m							1100	1947
	NWL, m							30.0	24.5
CW	Dis,m								1040
	NWL, m								23.5

Table 2.6.12 Average Model Volume as Compared to the Survey Volume in the As-built Plan

Wetland	Survey Volume (ML)	Model Volume (ML)	% Difference
Upper North	193.0	243.0*	+0.25
Upper West**	187.5	185.0	-1.3
Upper East	142.0	156.0	+9.8
Lower East	202.5	185.0	-8.6
Upper Bisa	628.0	625.0	-0.5
Central Wetland	1250.0	1115.8	-10.7

* including the whole UN6, UN7 and UN8
** excluding UW8

(2) For assessment of the water quality, the following assumptions have been made in this study.

a) the MIKE 11 computes flow condition as vertically homogeneous, the water quality parameters are fully mixed in the water column at each cross-sections.
b) the water processes take into account the immediate oxygen demand due to degradation of the dissolved and suspended organic matter. It implies that the reaction is immediate for oxygen uptake.
c) the water processes described above are the major controlling factors for water quality.
d) the simulation utilises an unsteady state to study the dynamic effects of the water quality aspects, neglecting the long term phenomena such as the retention of nutrients in the river system.

2.6.3.4 Model Water Quality Processes

(1) Preliminary runs (Appendix 2.4) of the Water Quality processes involve the following WQ parameters with their default global values:

(a) Oxygen processes

No. of reaeration expression	3
Reaeration temperature coefficient	1.024
Respiration of animals and plants at 20 deg.	3.000
Respiration temperature coefficient	1.047
Max. Oxygen production by photosynthesis	3.500
Displacement of oxygen production maximum	1.000

(b) Temperature

Latitude	3.000
Maximum absorbed solar radiation (kJ/m2/hour)	520.000
Displacement of solar radiation max from 12 pm	1.000
Emitted heat radiation (kJ/m2/hour)	67.000

(c) Denitrification

Reaction order	1st
Nitrate decay at 20 deg. C	1.000
Temperature coefficient for decay rate	1.160

(d) Nitrification

Reaction order	1st
Ammonium decay rate at 20 deg. C	1.540
Temperature coefficient of decay rate	1.130
Oxygen demand by nitrification	4.470

(e) Nitrogen contents

Ratio of ammonium released at BOD decay	0.290
Uptake of ammonium in plants	0.066
Uptake of ammonium in bacteria	0.109

(f) Degradation

1^{st} order decay rate at 20 deg. C	0.500
Temperature coefficient for decay rate	1.024
Half-saturation oxygen concentration	2.000

(g) Bed/ sediment

Sediment oxygen demand at 20 deg. C	0.500
Temperature coeff for sediment oxygen demand	1.000
Resuspension of organic matter	0.500
Sedimentation rate for organic matter	0.800
Critical flow velocity (net sed. = 0)	1.000

(h) Phosphorus contents

Ratio of P released at BOD decay	0.009
Uptake of P in plants	0.009

(i) Phosphorus exchange with the bed

Resuspension of particulate phosphorus	0.500
Deposition of particulate phosphorus	0.800
Critical velocity of flow (susp. = dep.)	1.000

(j) Phosphorus processes

Decay constant for particulate phosphorus	0.100
Temperature coeff for decay	1.000
Formation constant for particulate phosphorus	0.100
Temperature coeff for formation	1.000

(k) Coliforms

1^{st} order decay faecal	0.700
1^{st} order decay total	0.800
Temperature coeff for decay rate	1.090
Salinity coeff for decay rate	1.006
Light coeff of decay rate	7.400
Light coefficient	1.400
Salinity	0.000

2.6.3.5 *Model Calibration*

(1) The model was calibrated to the study data monitored by UPM together with the other water quality data collected. The model WQ parameters were determined by several iteration runs for this calibration process.

(a) Oxygen process

No. Of reaeration expression	1
Reaeration temperature coefficient	1.000
Respiration of animals and plants at 20 deg.	2.000
Respiration temperature coefficient	1.024
Max. Oxygen production by photosynthesis	1.000
Displacement of oxygen production maximum	0.000

(b) Temperature

Latitude	0.000
Maximum absorbed solar radiation (kJ/m2/hour)	0.000
Displacement of solar radiation max from 12 pm	0.000
Emitted heat radiation (kJ/m2/hour)	0.000

(c) Denitrification

Reaction order	1st
Nitrate decay at 20 deg. C	1.000
Temperature coefficient for decay rate	0.500

(d) Nitrification

Reaction order	1st
Ammonium decay rate at 20 deg. C	1.540
Temperature coefficient of decay rate	0.500
Oxygen demand by nitrification	4.470

(e) Nitrogen contents

Ratio of ammonium released at BOD decay	0.350
Uptake of ammonium in plants	0.066
Uptake of ammonium in bacteria	0.109

(f) Degradation

1st order decay rate at 20 deg. C, kBOD	0.100
Temperature coefficient for decay rate	1.000
Half-saturation oxygen concentration	4.000

At the following locations global values are substituted:

UW	:	kBOD=0.15
UN	:	kBOD=0.07
LE	:	kBOD=0.05
UE	:	kBOD=0.30

(g) Bed/ sediment

Sediment oxygen demand at 20 deg. C	0.500
Temperature coeff for sediment oxygen demand	1.100
Resuspension of organic matter	1.000
Sedimentation rate for organic matter	0.300
Critical flow velocity (net sed. = 0)	0.800

(h) Phosphorus exchange with the bed

Resuspension of particulate phosphorus	0.500
Deposition of particulate phosphorus	0.800
Critical velocity of flow (susp. = dep.)	0.800

At the following locations global values are substituted:

MAIN_LAKE	:	Critical flow=1.5
SIDE_LAKE	:	Critical flow=1.0
UN	:	Resuspension=0.55
UW	:	Resuspension=0.55
UE	:	Resuspension=0.57
LE	:	Resuspension=0.65

(i) Coliforms

1st order decay faecal	0.700
1st order decay total	0.800
Temperature coeff for decay rate	1.000
Salinity coeff for decay rate	1.006
Light coeff of decay rate	7.400
Light coefficient	3.000
Salinity	0.000

(2) The calibration used existing water quality parameters in the stream flow and runoff to the wetlands and lake as pollutant inputs as shown in Table 2.6.13. A normal year runoff in 1984 with an annual rainfall of 2153mm was used as the hydraulic inflow. The initial condition of the model, which is unstable, will not be taken into account.

Table 2.6.13 Water Quality for Stream Flow and Runoff for the Model Simulation

Parameter	Stream flow	Runoff
DO, mg/l	5.0	5.0
Temperature, ^{o}C	29	29
NH3, mg/l	1.0	0.3
NO, mg/l	1.0	1.0
BOD, mg/l	5.0 (for UW=3.0)	3.0
Dis.P, mg/l	0.3	0.1
Par.P, mg/l	0.4	0.1
F.coli, mil/100ml	0.008	0.001
T.coli, mil/100ml	0.015	0.005

(3) The simulated results in each wetlands, top and the last cell, and at the Primary Lake are as shown in the figures of 1984-run Time Series of Concentrations (see Appendix 2.5).

(4) The simulated results in each wetlands are consistent of the monitored data; reflecting the effect of runoff and the current state of wetlands. There is little degradation or removal of nutrients between the top and the last cell of each wetland.

(5) At the Primary Lake, from the 1984-run Time Series of Concentrations for Primary Lake, the nitrate is at the range of 0.85 to 0.95 mg/l as compared to the monitored values in Appendix 2.2 which is from 0.5 to 2.9 mg/l.. The values shown are for the Primary Lake at 1500 m, which is near to the site of the present Temporary Dam.

(6) For the BOD at the Primary Lake, the values are from 0.05 to 0.8 mg/l, as compared to the monitored values in Appendix 2.2 which is from 0.11 to 1.89 mg/l.

(1) For Total Phosphorus at the Primary Lake, the values of Dissolved Phosphorus and Particulate Phosphorus are from 0.01 to 0.10 mg/l and 0.01 to 0.04 mg/l as compared to the monitored values in Table 2.6.6 which is from 0.01 to 0.27 mg/l and 0.01 to 0.56 mg/l.

2.6.3.5 Model Scenarios

(1) Two scenarios are modelled. The first utilised existing top inflow pollutant concentration and estimated lateral inflow concentrations. Three hydrological conditions were used: normal, wet and dry hydrological years. The wet year of 1993 with an annual rainfall of 2730 mm and the dry year of 1988 with an annual rainfall of 1591 mm were used as hydraulic inputs (Table 2.6.13). The normal hydrological year is used for the calibration run. From the results of the first scenario, a second scenario was modelled. This used reduced phosphorus top inflow concentrations, but the same estimated lateral inflow concentrations. This second scenario will indicate the effect of water quality of the upper streams compared to the effect of lateral inputs from runoff and drains.

(2) The simulated results are as shown in Appendix 2.6 and Appendix 2.7, the 1993-run Time Series of Concentration and the 1988-run Time Series of Concentration. The water quality at the Primary Lake between the three scenarios are as shown in Table 2.6.14.

Table 2.6.14 Water Quality at the Primary Lake for the Model

	Wet Year	**Normal Year**	**Dry Year**	**Putrajaya Ambient Water Quality**
Nitrate, mg/l	0.9- 1.0	0.85- 0.95	0.86-0.92	7.0
BOD, mg/l	0.1- 1.6	0.05- 0.8	0.05-0.6	3.0
Dis.Phosphorus, mg/l	0.03-0.07	0.01- 0.10	0.01- 0.10	Total Phosphorus = 0.05
Par.Phosphorus, mg/l	0.01- 0.04	0.01- 0.04	0 - 0.04	
F. coli, c/100ml	0 - 200	0 – 100	0 - 100	100
Total coli, c/100ml	0 - 1000	0 - 300	0 - 200	5000

2.6.4 MODEL RESULT AND DISCUSSION

2.6.4.1 In Scenario 1, nitrate and BOD concentrations are below the Putrajaya Ambient Water Quality under the three conditions using the water quality concentrations assumed. BOD increases due to the higher hydraulic loading during the wet year as compared to the dry year. For Total Phosphorus, the values are at the Ambient Water Quality of 0.05 mg/l or higher for the three scenarios. Therefore, phosphorus will appear to be the factor that will affect the lake water quality under the current loading conditions.

2.6.4.2 In Scenario 2, despite the reduced Phosphorus loading from incoming streams, the values of Phosphorus in the Lake showed little discernable change. This indicates that the unchanged lateral inflows play an important role in controlling the Lake water quality.

2.6.4.3 Based on the model results for the wet, dry and normal year in Table 3.2.17, nitrate and BOD meet the Putrajaya Ambient Water Quality under these three conditions with existing water quality. BOD increases with hydraulic loading during the wet year as compare to the dry year.

2.6.4.4 For Total Phosphorus, the values are at the Ambient Water Quality of 0.05 mg/l or higher for the three scenarios. Phosphorus will appear to be the factor that will affect the lake water quality under existing condition.

2.6.4.5 The present concentration of Total Phosphorus of 0.7 mg/l, into the inflow waters of the wetlands at the upper portion, is unable to be reduced for input to the Primary Lake system. This is because present wetland removal, overall, does not appear to be occurring. There is little change, indicating degradation or removal, of nutrient concentration between the top and the last cell of each wetland series. This contrasts with the previous AQUALM model results obtained in the Putrajaya Lake Phase 1 where removal efficiencies of 20%-80% for phosphorus were expected.

2.6.4.6 The causes of the dissimilarity between the AQUALM model and the MIKE11 model is at yet uncertain. Several factors are different between the models:

(a) tr.eatment of wetland cells as a single entity rather than separate cells,
(b) no lateral inflow to the wetlands,
(c) calibration to Australian conditions instead of actual existing conditions.

2.6.4.7 The advantage of this study is the ability to use the present monitoring data to calibrate the model. The previous AQUALM model could only be calibrated on speculation of removal efficiencies.

2.6.4.8 The efficiency of each cell is not calculated due to the variable pattern of parameter concentration in each wetland cell as indicated in the UPM monitoring of each wetland cell.

2.6.5 Recommendation

2.6.5.1 The lateral inflow of runoff to the wetlands and lake affects the water quality greatly. It could be the reason why there is little degradation or removal of nutrients between the top and the last cell of each wetlands. There should be continuous water quality monitoring as recommended in the Lake Management Guidelines.

2.6.5.2 **The construction activities at the surrounding areas may contribute adversely to the water quality in the lake and careful control of such activities is vital in the immediate term.**

2.6.5.3 **To reduce non-point source pollutant inflow, particularly of nutrients and agricides, it is recommended that riparian buffer zones, on both sides of the drainage lines and water bodies, be built. This is to trap and reduce the sediment and other pollutants in the surface runoff, and interflow, from entering the water system.**

2.7 THE WETLANDS

2.7.1 Wetland Ecological Status

2.7.1.1 The Lake and Wetland System

(a) The Putrajaya Lake System

(1) The Putrajaya Lake system comprises of the primary Putrajaya Lake and six artificial wetlands as shown in Figure 2.7.1. The six artificial wetlands are the Upper West (8 cells), Upper East (3 cells), Upper North (8 cells), Lower East (2 cells), Central (1 cell) and the Upper Bisa (2 cells) Wetlands. The wetlands have been designed as a measure to improve the runoff and enhance the water quality in the Lake and as another natural landscape feature of the "Garden-in-a-city concept" of Putrajaya. They

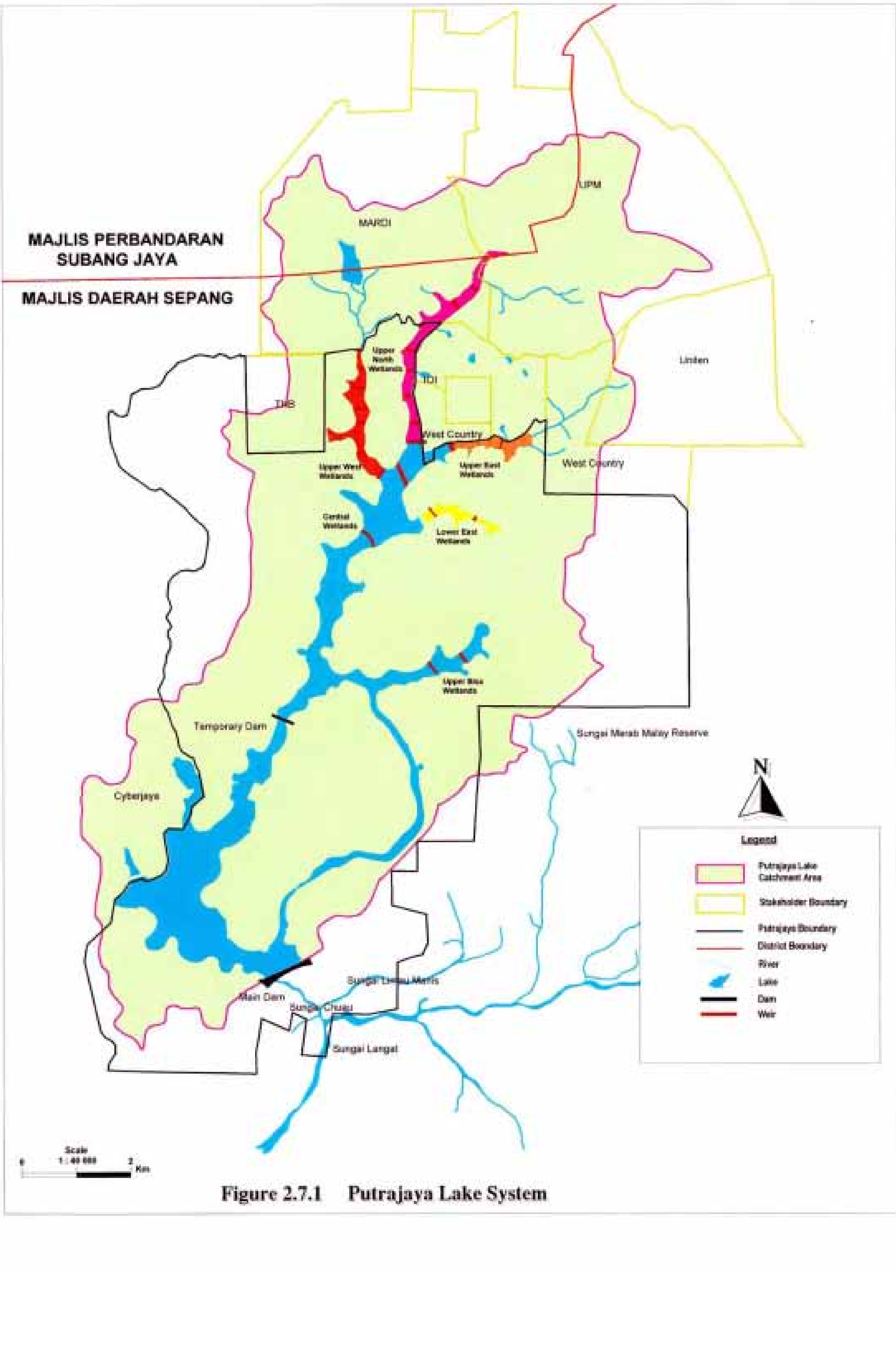


Figure 2.7.1 Putrajaya Lake System

have been designed as secondary measures for the reduction of runoff pollutants into the Lake. The primary measure is through implementation of appropriate land-use control and innovative drainage design in the catchment.

(2) Figure 2.7.2 shows the typical cross-sections of two tropical wetlands of different widths. The forests and shrubs are located along the intermittent flooding zones of the banks of the wetlands whereas the macrophytes of the marshlands are contained within the litoral zones. A total of about 6 million indigenous plants, shrubs, palms, ferns and trees, taken from more than 70 wetland sites around the country, are being used to create the marshlands and "forests" along the intermittent flooding zones of the banks of the wetlands and the primary Putrajaya Lake.

(b) Wetland Plant Nutrient Uptake

(1) There has been no comprehensive study to date on the rate at which the nutrients are absorbed in the plant cells of individual species. Thus it is difficult to assess individual wetland species of each wetland cell as regards to their role in improving the lake water quality. Nevertheless, some information is available about the main wetland species that were planted in all wetland cells throughout the wetland system. They are as follows:

- *Lepironia articulata* holds high biomass, 2 kg dry wt./m^2, implying high nutrient sink and microbial carrying capacity.

- *Eleocharis* sp. holds high biomass varying 1.5 and 2.5 kg dry wt./m^2, holds high nutrient uptake capacity and can withstand high fluctuation in flow rates.

- *Phragmites karka* holds high nutrient uptake capacity and provides refuge for fish and other invertebrates. Withstand high fluctuation in flow rates, turbidity and nutrient loadings.

- *Scleria* sp. has low foliage, holds high nutrient uptake capacity and provides refuge for fish and other invertebrates. Withstands high fluctuation in flow rates, turbidity and nutrient loading.

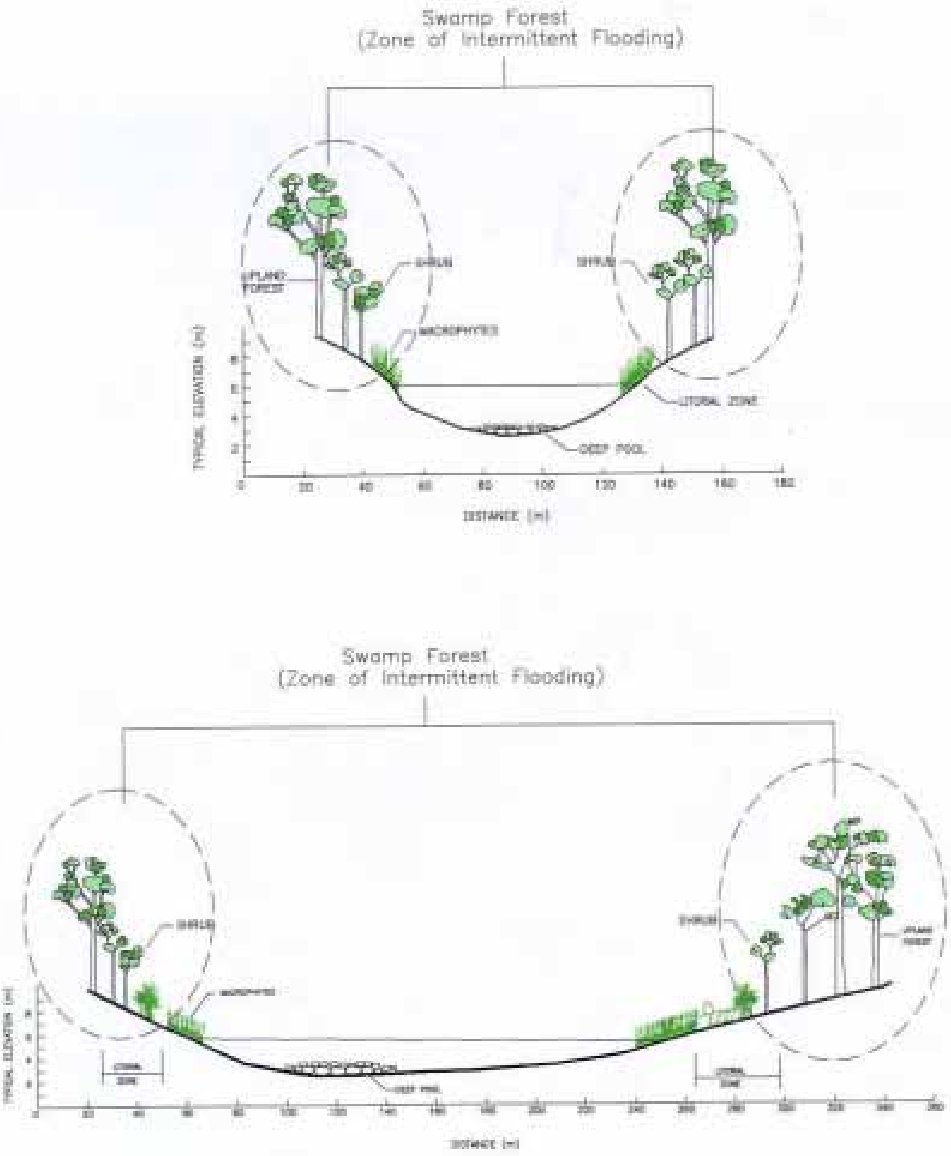


Figure 2.7.2 Typical Cross-section of a wetland

(2) Some information on nutrient uptake by temperate species grass crops are also available (Table 2.7.1) based on fertilizer requirements. The information indicates that selection of species can have different implications for nutrient uptake.

(3) From the field study it was found that planting in the Upper North, Upper West, Upper East and Lower East Wetlands have been completed while those for the other wetlands are still in progress. Terrestrial plants have also been planted in the intermittent flooding zone of the banks of the Upper North, Upper West, Upper East, and Lower East Wetlands, whereas, the zones along the banks of the Central and Upper Bisa Wetlands, and the primary Lake will be developed into swamp forest to provide habitats for a variety of fauna.

Table 2.7.1 Nutrient uptake rates for selected crops

Crop	**Nutrient Uptake lb/acre.yr**		
	Nitrogen	Phosphorus	Potassium
Forage Crops			
Alfalfa	200-480	20-30	155-200
Broome grass	116-200	35-50	220
Coastal Bermuda grass	350-600	30-40	200
Kentucky bluegrass	180-240	40	180
Quack grass	210-250	27-41	245
Reed canary grass	300-400	36-40	280
Rye grass	180-250	55-75	240-290
Sweet Clover	158	16	90
Tall Fescue	135-290	26	267
Orchard Grass	230-250	20-50	225-315

Source:` Metcalf & Eddy, 1991. Wastewater Engineering - Treatment, Disposal & Reuse. McGraw-Hill.

2.7.2 Flora

An inventory of the flora planted and to be planted in the six wetlands and the primary Lake given below. This was based primarily on secondary information supported by field survey where pertinent. The references consulted are Idris and Rozaina (1992), Holttum (1954), Corner (1978), Ng (1978), Pancho and Soerjani (1978), and Wyatt-Smith and Kochumen (1979).

2.7.2.1 Upper North Wetland

The Upper North Wetland consists of eight cells, each with a number of plots planted with single wetland plant species (mono-culture), as shown in Figure 2.7.3. The wetland plant species in each cell are also shown in the figure whereas the terrestrial plant species planted along the banks of the wetlands are given in Table 2.7.2. Incoming water, laden with organic and inorganic pollutants, enter into the uppermost wetland cell (UN8) and passes from one cell to another via weirs. During the process suspended sediments will settle to the bottom while the nutrients will be taken up by a variety of wetland plant species in the various cells.

2.7.2.2 Upper East Wetland

The Upper East Wetland consists of three cells, each with a number of plots planted with single wetland plant species (mono-culture), as shown in Figure 2.7.4. The wetland plant species in each cell are also shown in the figure whereas the terrestrial plant species planted along the banks of the wetlands are given in Table 2.7.3.

Table 2.7.2 Terrestrial Plants in the Upper North Wetland

Scientific Name	Common English/ Malay Name
Caryota mitis	Fish Tail Palm – Rabok, tukas
Cerbera odollam	Pong Pong
Colocasia gigantea	Keladi
Crinum asiaticum	
Cyrtostachys renda	
Dillenia suffruticosa	Simpoh Air
Eugenia aquae	Jambu Air
Ixora javamica	Siantan
Melaleuca cajuputi	Gelam
Pometia piumata	Kasai
Flagellaria indica	
Arundina graminifolia	Bamboo Orchid
Saraca thaipingiensis	Seraca
Fagraea fragrans	Tembusu
Eugenia obana	Kelat
Ploiarum atternifolium	Riang-riang
Shorea sp	
Ficus microcarpa	
Ficus benjamima	
Eugenia grata	
Alocasia macrrhiza	

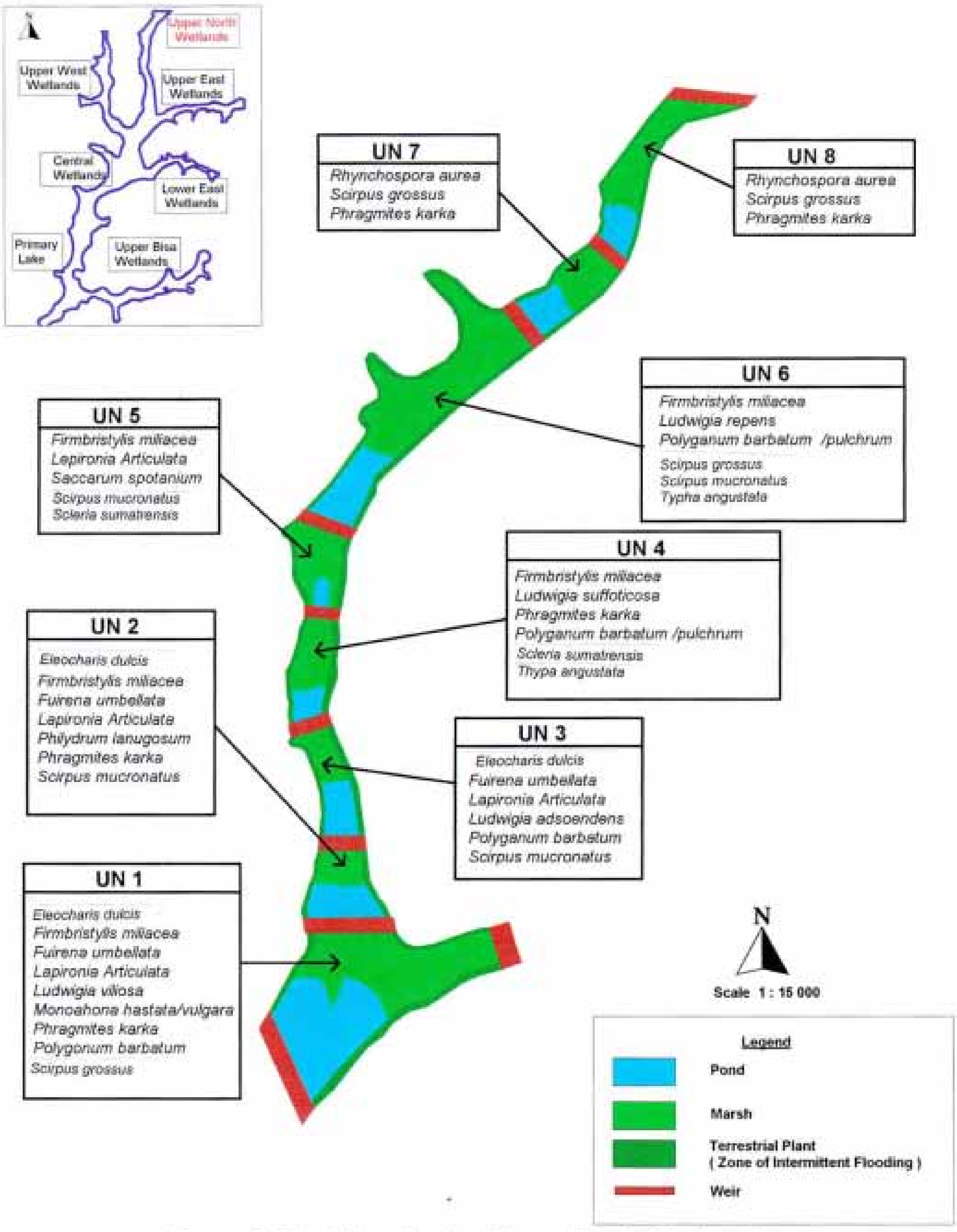


Figure 2.7.3 Flora in the Upper North Wetland

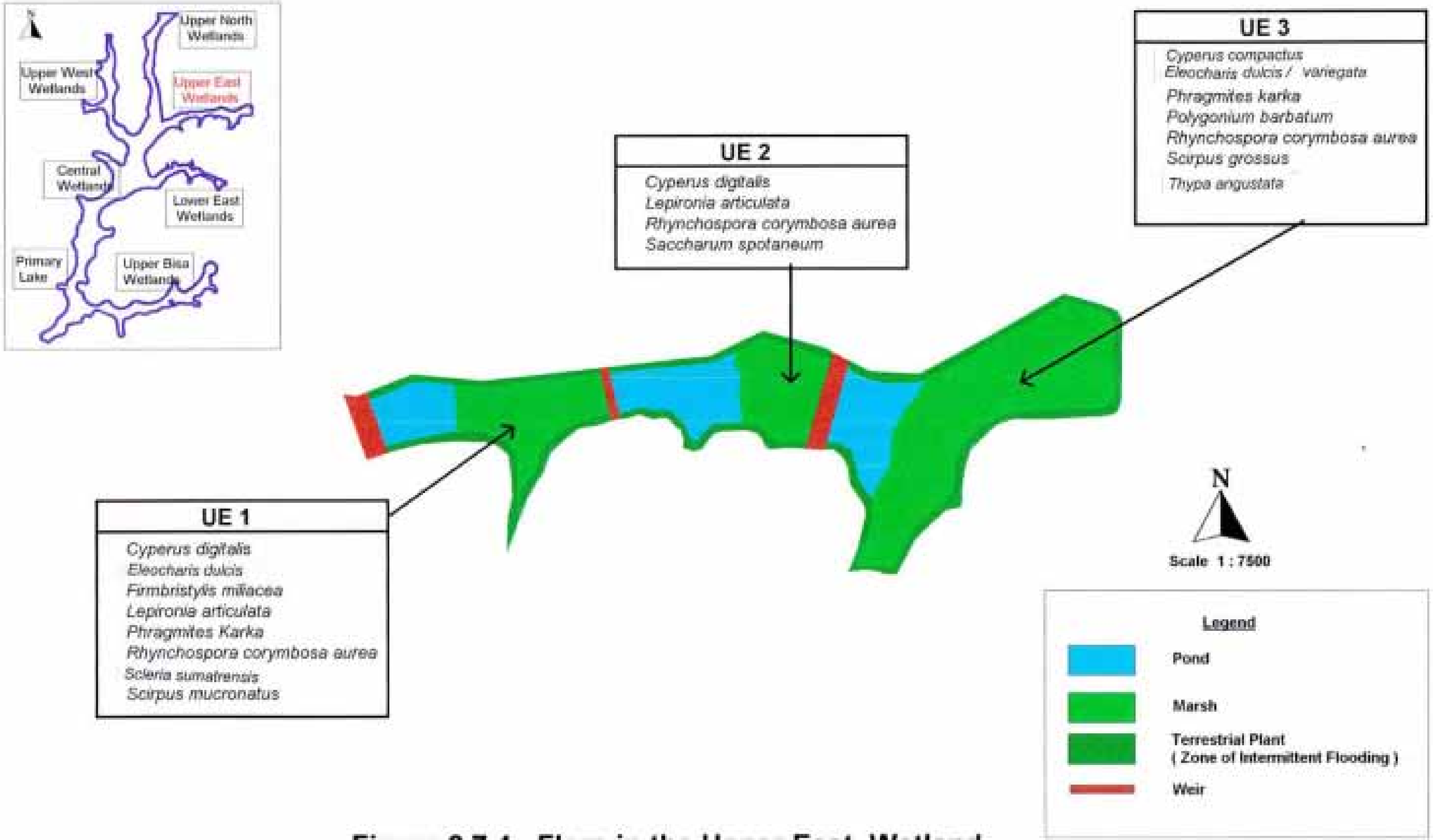


Figure 2.7.4 Flora in the Upper East Wetland

Table 2.7.3 Terrestrial Plants in the Upper East Wetland

Scientific Name	Common English/ Malay Name
Alstonia spathulata	Pulai Paya
Caryota mitis	Fish Tail Palm
Cerbera odollam	Pong Pong
Colocasia gigantea	Keladi
Crinum asiaticum	Sea Shoce Crinum
Cyrtostachys renda	Sealing Wax Palm
Dillenia suffruticosa	Simpoh Air
Eugenia aquae	Jambu Air
Ixoea javamica	Siantan
Melaleuca cajuputi	Gelam
Pometia pirmata	Kasai
Flagellaria indica	
Arundina graminifolia	Bamboo Orchid
Saraca thaipingiensis	Seraca
Fagraea fragraus	Tembusu
Hibiscus tilleaceas	Hibiscus
Eugenia obana	Kelat
Ixora finlaysonia	Siantan
Ficus microcarpa	
Ficus berjamina	
Shorea Sp.	

2.7.2.3 Upper West Wetland

The Upper West Wetland consists of eight cells, each with a number of plots planted with single wetland plant species (mono-culture), as shown in Figure 2.7.5. The wetland plant species in each cell are also shown in the figure whereas the terrestrial plant species planted along the banks of the wetlands are given in Table 2.7.4.

2.7.2.4 Lower East Wetland

The Lower East Wetland consists of two cells, each with a number of plots planted with single wetland plant species (mono-culture), as shown in Figure 2.7.6. The wetland plant species in each cell are also shown in the figure whereas the terrestrial plant species planted along the banks of the wetlands are given in Table 2.7.5.

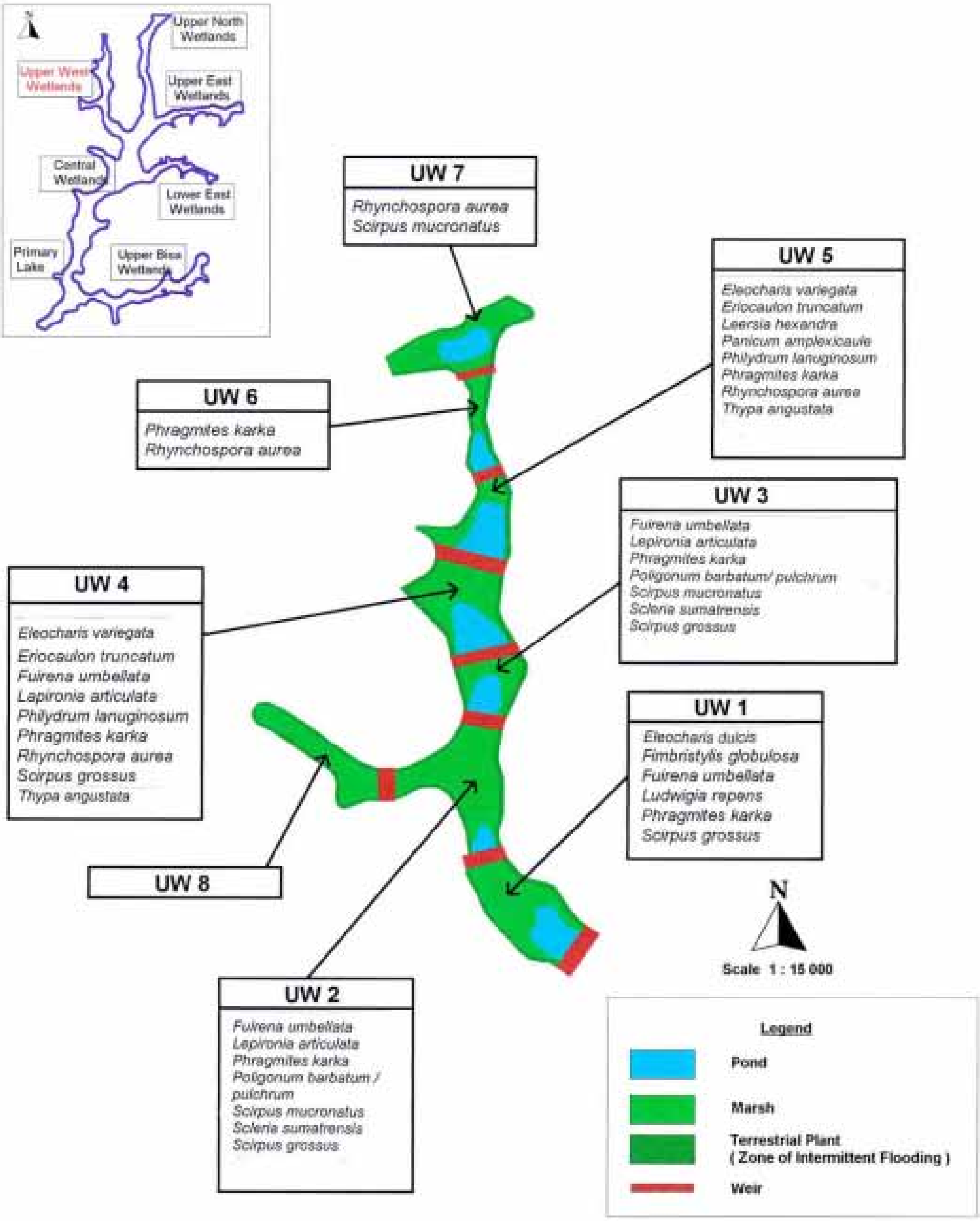


Figure 2.7.5 Flora in the Upper West Wetland

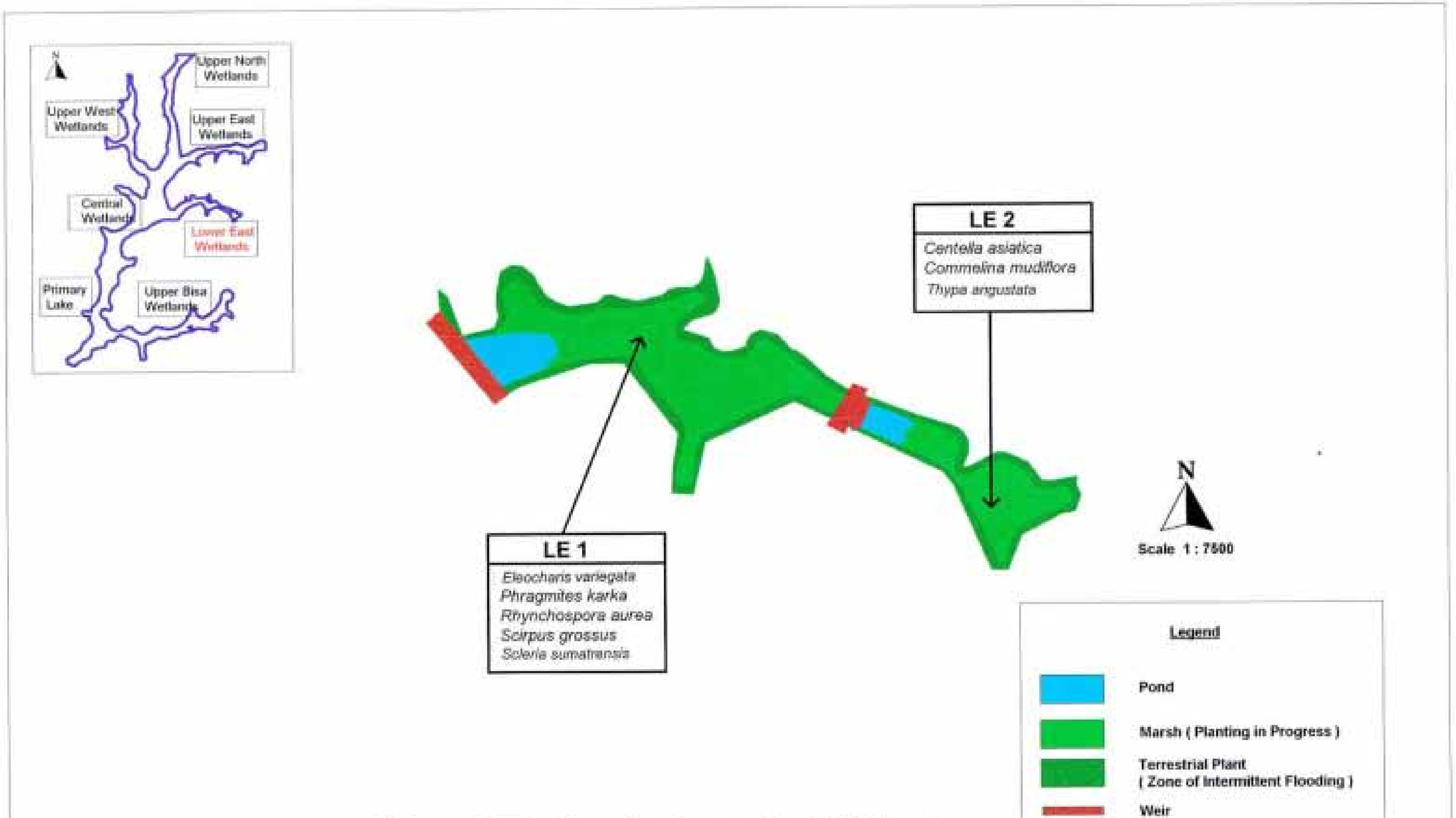


Figure 2.7.6 Flora in Lower East Wetland

Table 2.7.4 Terrestrial Plants in the Upper West Wetland

Scientific Name	Common English/ Malay Name
Alstonia spathulata	Pulai Paya
Alstonia angustiloba	Pulai
Caryota mitis	Fish Tail Palm
Cerbera odollam	Keladi
Colocasia gigantea	Keladi
Crinum asiaticum	Sea Shore Crinum
Cyrtostachys renda	Seabing Wax Palm
Dillenia suffruticosa	Simpoh Air
Engenia aquae	Jambu Air
Ixoea javamica	Siantan
Lubirgina villosa	Malaysia Willow Herli
Melaleuca cajuputi	Gelam
Pometia pirnata	Kasai
Arundina graminifolia	Bamboo Orchid
Saraca thaipingiensis	Seraca
Fagraea fragrans	Tembusu
Licuala spinosa	Palas
Ploiarum altermifolium	Riang riang
Ixora finlaysonia	Siantan
Eugenia obana	Kelat
Koompasia malaccensis	Tualang

2.7.2.5 Upper Bisa Wetland

The Upper Bisa Wetland consists of two cells, each with a number of plots planted with single wetland plant species (mono-culture), as shown in Figure 2.7.7. The wetland plant species in each cell are also shown in the figure whereas swamp forest trees will be planted along the banks of the wetlands. The swampy habitat will allow the colonisation of the wetland by fauna (mammals, amphibians and birds). Since planting has not started yet a list of the tree species could not be provided.

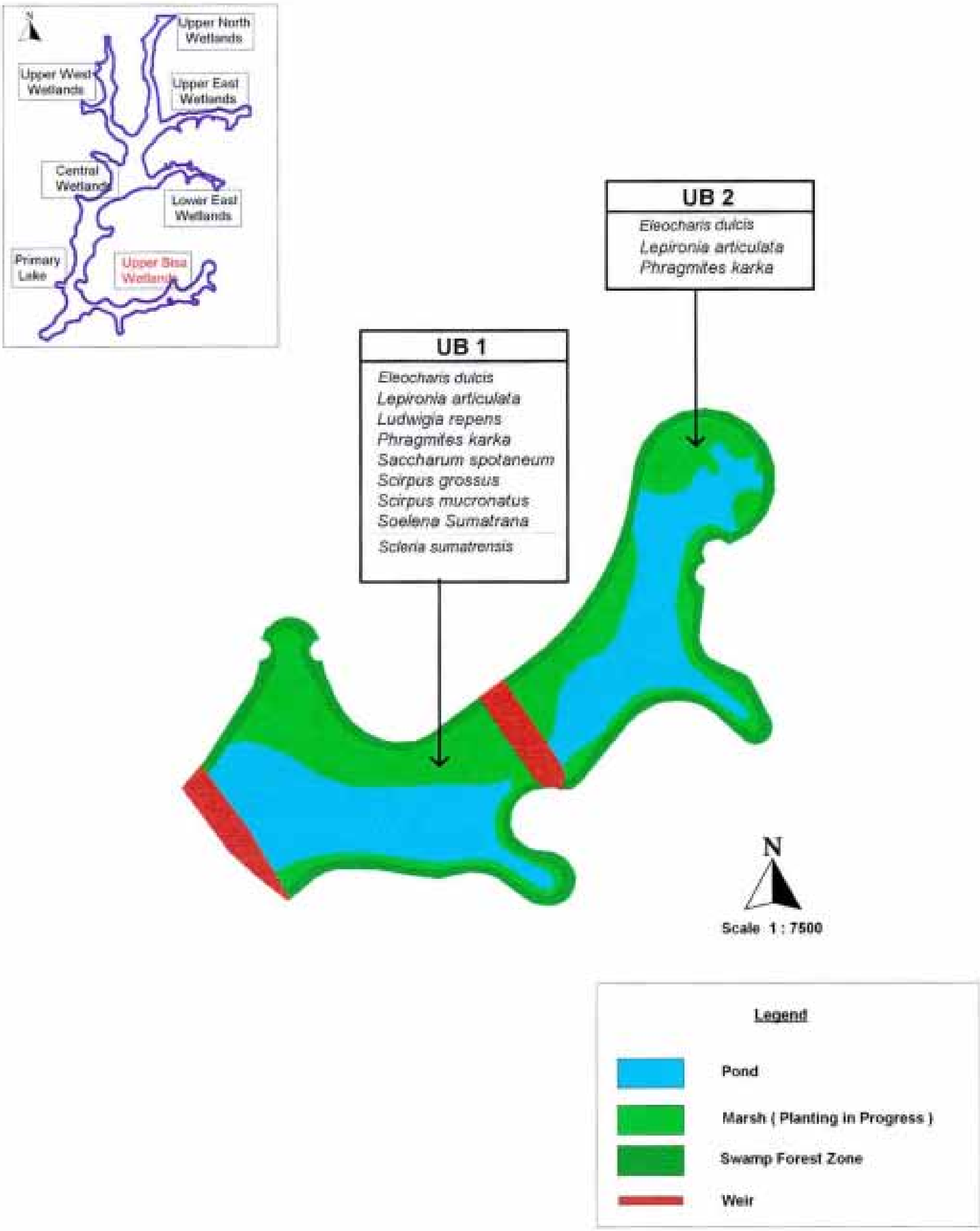


Figure 2.7.7 Flora in the Upper Bisa Wetland

Table 2.7.5 Terrestrial Plants in the Lower East Wetland

Scientific Name	Common English/ Malay Name
Alocasia macrorrhiza	
Colocasia gigantea	
Crinum asiaticum	Sea Shore Crinum
Dillenia suffruticosa	Simpoh Air
Ixora javamica	Siantan
Ludwigia villosa	Malaysia Willow herb
Melaleuca cajuputi	Gelam
Arundina graminifolia	Bamboo Orchid
Saraca thaipingiensis	Seraca
Fagraea fragrans	Tembusu
Hibiscus tilleaceus	Hibiscus
Ixora finlaysonia	Siantan
Eugenia obana	Kelat

2.7.2.6 Central Wetland

The Central Wetland (Figure 2.7.8) is only one cell and has water depths exceeding 5 m. Wetland species cannot survive in such deep water. Thus, most of the wetland species are being planted along the limnetic zone (marshy area) around the periphery. The planting exercise has just started and is currently in progress. The incomplete list of the wetland plant species is given in Figure 2.7.8. Swamp forest trees will be planted along the banks of the wetlands. Since planting has not started yet a list of the tree species could not be provided.

2.7.2.7 Primary Lake

Like the Central Wetland, the primary Lake (Figure 2.7.9) has depths exceeding 5 m, and wetland species cannot survive in such deep water. Thus, most of the wetland species are being planted along the marsh zone around the lake side. The planting exercise has just started and is currently in progress. The incomplete list of the wetland plant species is given in Figure 2.7.9. Swamp forest trees will be planted along the banks of the wetlands. Since planting has not started yet a list of the tree species could not be provided.

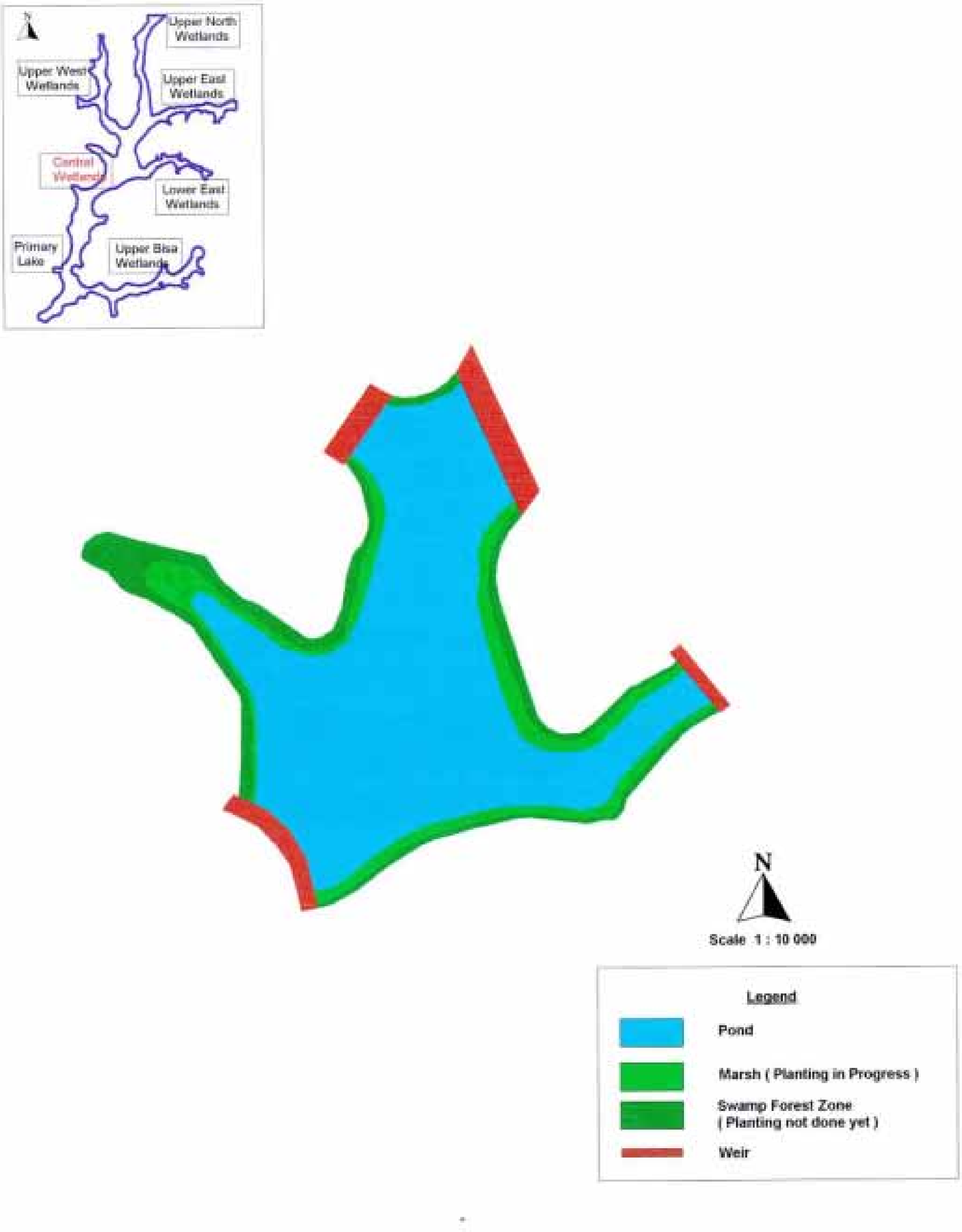


Figure 2.7.8 Flora in the Central Wetland

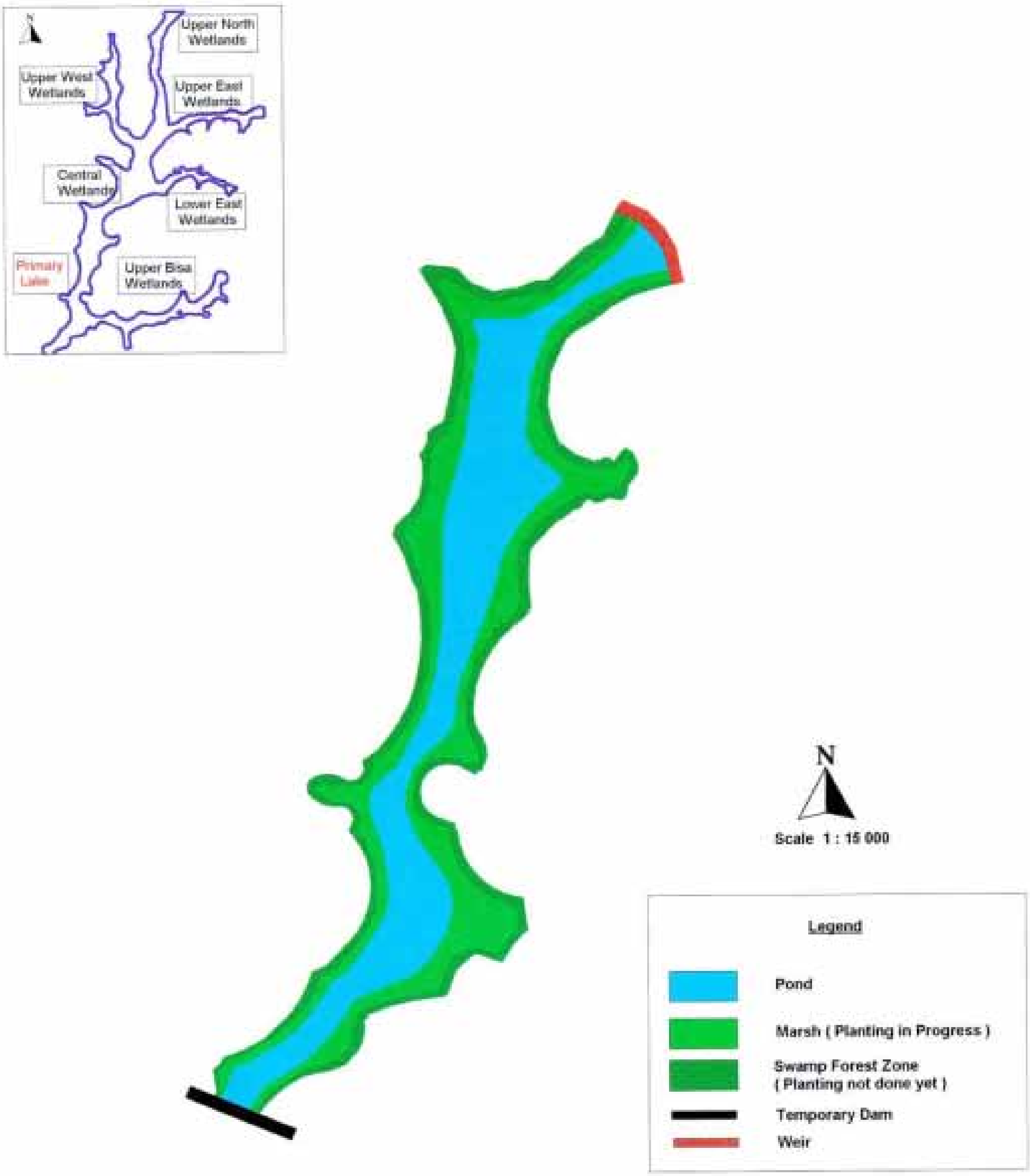


Figure 2.7.9 Flora in the Primary Lake

2.7.3 Fish and Fauna

An inventory of the fauna (birds, amphibians and mammals) and fish stock is given based primarily on secondary information and supported by field survey where pertinent. The following are the results from the study.

2.7.3.1 Fish

(1) The identification of fish species were based on taxonomic keys developed by Alfred (1964), Mohsin and Ambak (1982), Inger and Chin (1962), Ng, et. al. (1992) and IUCN (1994). No records of fish sampling survey for the stretch of Sg. Chuau, which has been impounded to form the Putrajaya Lake system has been found. However, general information are available which indicated that the Sg. Chuau is rich in a variety of indigenous and exotic species (Mohsin and Ambak, 1982).

(2) Some of the common species are *Puntius gonionotus*, *Puntius schwanenfeldii*, *Puntius* Spp., *Rasbora* Spp., *Trichogaster pectoralis*, *Clarias batrachus*, *Channa striatus*, *Tilapia* Spp., *Notopterus notopterus*, *Macrobrachium lancestri*. Due to the impoundment the habitat of the species has now changed from riverine to lacustrine. The species will thrive well in the lake because of the availability of shelter, rich feeding and breeding grounds in the lake. It is also known that fish stocking exercise has also been carried out after the impoundment of the river. Table 2.7.6 shows the species introduced into the Putrajaya Lake system.

2.7.3.2 Fauna

(1) With site clearance, earthwork and construction activity in the catchment, the diversity of the fauna population have been greatly reduced. However, since the constructed wetlands will provide a good habitat for the fauna, colonisation by the fauna such as birds are expected. The wetlands are located near a flyway which crosses the new international airport at Sepang near Putrajaya. The flyway is the flying route for migratory birds from the west during overwintering period. The birds fly over Putrajaya and Sepanang of West Malaysia to Indonesia. Thus there is a possibility of significant colonisation of the wetlands by water birds in the near future.

Table 2.7.6 Fish Species introduced into the Putrajaya Lake system

Scientific Name with Local/ English Name	Ecological Attributes
Puntius tetrazona (Tiger Berb)	Predate mosquito, zooplankton feeder and indigenous and have high ornamental value
Puntius gonionotus	Indigenous, Insectivorous and zooplankton feeder and sport fish with ornamental value
P. schwanenfeldii (Lampam Jawa)	Insectivorous, zooplankton feeder, ornamental value indigenous and good sport fish
Rasbora Spp. (Seluang)	Ornamental species, Predate mosquito larvae, insects and some aquatic plants.
Trichogaster pectoralis (Sepat)	Indigenous, control algal population and resistant species
Betta splendens (Ikan laga)	Feed both phyto- and zooplankton, ornamental value.
Aplochilus panchax (Kepala Timah/Whitespot fish)	Insectivorous and predate mosquito larvae
Xenontodon cancila (Needle fish)	Insectivorous and predate mosquito larvae.
Leptobarbus hoevenii (Jelawat)	Phytoplankton feeder, also feeds on aquatic plants, good ornamental fish
Channa striata (Haruan)	Carnivorous and predate small fish and mosquito larvae

(2) A general survey of the fauna in the area after the impoundment phase was undertaken. It was observed that amphibians such as the crab-eating frog (*rana cancrivora*) and cricket frog (*rana limnocharis*) were found in the area. Species of waterfowl and heron were also spotted. The bird species observed are given in Table 2.7.7 whereas the mammals are given in Table 2.7.8.

Table 2.7.7 Birds species observed in the Putrajaya Lake system

Scientific Name	Environmental Status
Charadrius leschemaultii	P*
Egretta eulophotes	P
Xenus cinereus	P
Tringa Spp.	P
Nycticorax Spp.	P
Haliastur indus	P
Malacopteron Spp.	P
Trichastoma Spp.	P
Prinia Spp.	P
Phylloscopus Spp.	P
Loriculus galgulas	P
Halcyon Spp.	P

P* - 'Protected' species according to the *Wildlife Protection Act, 1972*.

Table 2.7.8 Mammal species observed in the Putrajaya Lake system

Scientific Name	Environmental Status
Macaca fascicularis	P*
Presbytis obscura	P
P. cristata	P
Callosciurus prevostii	P
Ratufa bicolor	P

(3) The primary information collected indicates that there are incidences of colonisation of the Putrajaya Lake system by the fauna. However, it will take some time for the wetlands and open water lake to have a fully developed fauna population.

2.7.4 Recommendations for Sustaining the Fauna & Flora

2.7.4.1 Wetland Plants

(a) Plant Harvesting

(1) Plant die-off, due to overcrowding, pest infestation and weed's invasion in the wetland cells, is common and expected. It should not interrupt the ecological cycle as each wetland cell has its own microbial carrying capacity.

However, if the die-off is significant involving large planting area, there will be need for harvesting. Thus, routine harvesting of senescent plants due to disease or overcrowding or to reasons unexplained, is very appropriate and this exercise to be completed during drought period rather than monsoon. Plant harvesting will have environmental impacts on water quality and fish and invertebrates and it must be addressed properly. One of the options to maintain the water quality, is to raise temporarily the stop logs in the weir to increase retention time by increasing volume. This will allow for the sediments to settle at the bottom. The rise in the stop logs will temporarily stop water flow into the downstream.

(b) Planting Density

(2) Planting density is to be as low as possible so as not to repeat the past experience of overcrowding of plants in some of the cells. The previous density for planting the wetland cells is relatively high, varying from 15-18 plants/m^2. The recommended density for transplanting the harvested cells is as follows:

- *Scleria* sp. - <6 plants/m^2
- Others, such as *Phragmites* sp. *Lepironia* sp. and *Scirpus* sp. - <10 plants./m^2

(c) Species Selection

(3) Currently there is limited information on the ability of an individual wetland species to uptake of particular nutrients at a particular aquatic habitat type. The wetlands at Putrajaya represent an excellent opportunity for research into this area.

(4) It is generally known that Nitrogen, Phosphorus and Potassium are three major nutrient elements required for the growth and propagation of plant species including those of wetland plants. But the intricate physiology of nutrient uptake and cellular absorption are little known. Especially very little is known particularly on the tropical and equatorial wetland plants with some information available from temperate regions (section 2.7.1.2). However, the information available on the temperate

wetland plants may be of little relevance to the tropical wetland species because of the different rates and annual pattern of growth, and the temperature difference which may affect the rates of the biochemical processes themselves. Nevertheless, some general information which may be applicable of the tropical wetlands which are shown in Table 2.7.9.

Table 2.7.9 Plant species and nutrient uptake

Species	Information Available
Phragmites karka	Ability to polish sewage effluents
Lepironia articulata	High nutrient absorber
Saccharum sp.	Good nutrient absorber, shading and refuge for fish
Scirpus grossus	Good nutrient absorber

(5) Although other wetland plant species are well known to have ability in nutrient uptake in cleaning up of euthrophicated lakes, ponds, reservoirs and marshland, quantitative field experiments have not been done yet. As such precise information are not available.

(6) For the shoreline, Elephant Grass, *Scleria* sp. is less foliaceous and fast growing. It is relatively more resistant than other species and withstands more water level fluctuation in the cells. As a replacement of harvested species, it can be given priority.

(d) Control of Unwanted Aquatic Weeds

(7) Weeds are the major problems in the non-inundated or improperly inundated cells than in the inundated ones. They are prevalent in UN 5, UN6 and UW5, UW6 and UW7 and also in the Lower East wetland. Weeds are competitive and fast growing compared to wetland plants. They are resistant to harsh environment. Common weeds in the wetland are Mimosa, *Pudica* sp. *Galinsoga* sp. *Rhyncospora* sp. *Fimbristylis* sp. and *Limnocharis* sp.

(8) The following steps are to be taken:

- Continuous monitoring

- Manual weeding to be done periodically and consistently in all wetland cells. The exercise has to be limited to noxious and exotic species.

- Maintain the required water level so that weeds are submerged under water. This will prevent further germination of seeds and seedlings.

- Manual weeding of oil palm seedlings in UN 5 and UN 6. They are found in large numbers in Upper North Wetland.

(9) A successful way of removal of unwanted aquatic weeds is by the use of biodegradable herbicides which would have little effect on fish and other invertebrates. The pesticide BMP can be consulted for appropriate herbicides. Regular manual weeding is the best non-polluting method.

(e) Pest Infestation

(10) Pest problems have been documented at early stage (Putrajaya Constructed Wetlands, Advisory Report # 8, Wetland International -Asia Pacific). Disease attacks on some wetland plants in UN and UW cells are also found in the present study. *Phragmites karka* and *Scirpus grossus* were found to have been attacked by aphids and stem borer respectively. This was found sporadically in some cells. The problems are, however localised and can be addressed effectively. The following steps are to be considered for action immediately.

1. To develop an Integrated Pest Management Techniques (IPM). IPM is a well-established pest management system whereby pests are killed at a threshold level without having any impact on non-target organisms.

2. Immediate harvesting of the infected plants and transplanting with new plants. Planting density must not exceed 10 sp./m^2 for species other than Elephant Grass. Elephant Grass, *Scleria* can be planted more

than *Phragmites karka* due to latter's resistance to environmental constraints.

3. Biological control method using natural predators of pest and insects. Biopesticide, *Bacillus thuringinesis* can control the pests namely caterpiller leaf rollers (*Craphalocrocis medinalis*) and rice step borer, *Scirpophaga incertulas*.

(f) Water Level management

(11) Maintenance of required water level is extremely important for survival and propagation of wetland plants. Water level varies with rate of establishment of wetland plants. Shortage or lack of water in UN 5, UN 6 and UW 5 has put wetland plants under stress and reduced plant vigour. It increases the chance of secondary attack by pests. Water level in UN 5 and UN 6 should be increased to control of unwanted aquatic weeds at the fringe of the marsh zone and to make available adequate nutrients and pollutants to variety of wetland plants. Water level rise in UN 5, UN 6, UW 5, UP 6, and UW 7 is also recommended to allow fish to feed on the marginal and shallow marsh.

(g) Monitoring Plant Performance

(12) It is expected that a plant biologist/botanist or horticulturist will be involved in the vegetation monitoring. The following points have to be considered and provide biological indicators of plant health:

1. The colour of plant leaves should be monitored;

2. Leaves should be observed for chlorosis;

3. Removal of plant litter manually;

(13) Removal of plant litter at the substratum can be achieved by ensuring the following:

1. Water circulation from upstream to downstream via wetland cells and primary lake;

2. Establishment of roots of wetland plants into the substratum;

3. Stocking more detritivorous, and omnivorous fish species in the wetland cells.

(h) Plant Nursery

(14) Supply wetland plants as, and when, necessary, to replenish the harvested plants is crucial to operation and management of wetland system. The outdoor nursery should be ideally located within the Putrajaya wetland at a strategic location so that they can be supplied readily in any affected wetland arms. The wetland nursery used by the wetland contractors is suitable.

(15) Periodic replanting will be necessary in wetland arms due to die off and occasional harvesting of overcrowded and diseased plant species. In the outdoor nursery, at least 1% of seedlings of all wetland species planted in six constructed wetlands should be readily available for replanting purpose as and when necessary. This amounts to approximately 20,000 – 25,000 wetland plants, of the various species, which will have to be propagated in the outdoor nursery.

(16) All the potted wetland plant species should attain a reasonable height before they are ready for transplanting purpose. The wetland plant species height will vary depending upon the location and depth of water body of the replanting area in question.

(i) Wetland Plant Monitoring

(17) Long term monitoring and management are important for maintenance of a healthy wetland system. Weekly supervision of general health of all dominant plant species in the wetland cells is to be undertaken. Immediate actions are to be taken for remedy if incidences of any of the following are apparent:

1. Lack/shortage of water in any of the wetland cells; water levels should be in the region of 0.3 to 2 m for aquatic plant growth.

2. Overcrowding of any of the species in the cells that have caused stress, pest infestation and reduced plant vigour resulting in the stunting of growth.

3. Insect attack of significant proportion in any of the species in the wetland cells.

4. Illegal poaching on wetland plants for hunting purpose.

(j) Community Awareness and Education

(18) Apart from the bio-chemical and other physical controls, community awareness and education amongst common people to appreciate wetland and its associated plants are important for their conservation and management.

2.7.4.2 Fish Community

(a) Fish Species

(1) There has been fish stocking in Putrajaya wetland system in late 1998. Prior to this an inventory of fish naturally occurring the water system was established by fish sampling using locally available fishing gears. The inventory included both indigenous and exotic species. The dominant local species were those of Cyprinids and Clariids. Other than the species of these families, indigenous, *Channa striatus* and exotic Tilapia, *Oreochromis mossambicus*, were also dominant species recorded.

(2) The fish stocking exercise included the release of both local and exotic species, the major species of the former being *Betta pugnax* and *Trichogaster pectoralis*, *Clarias* sp., *Puntius* sp., Osphronemus sp. And *Channa* sp. The exotic species to be stocked at later stage are grass carp and bighead carp. The objective of fish stocking is to control mosquito larvae, maintain good water quality and support sport and recreational fishery.

(3) The performance of the fish community in achieving the objective is not fully known. Nonetheless, our frequent survey in wetland cells of UN, UW, UE, LE, and UB indicated that species of exotic Tilapia, and indigenous *Trichhogaster* sp. (Sepat Siam), and *Rasbora* sp.

(Seluang), *Puntius* sp., *Channa* sp. (Haruan), *Betta* sp. (Pelaga) are well established. The overgrowth of Tilapia is a cause of concern and the following control measures are necessary:

(b) Control of Undesirable Species

(4) Removal of *Channa* sp. (Haruan) and *Pectoralis* sp. (Sepat Siam) from the wetland system may prove to be costly and unwise as the species are known to feed effectively on mosquito larvae. Mosquito breeding in shallow and stagnant creeks and marsh are commonly expected. Species of Tilapia is always a nuisance to the aquatic system for its fast growing nature which if not controlled will affect other fish species. They can be controlled by:

1. Fish sampling using netting (cast and gill netting) and scooping

2. Angling and sport fishing

3. Biological control by introducing more predatory sport and game fish.

(5) Some species need to be controlled at the early stage. Generally, the Grass carp, *Ctenopharyngodon idellas*, is the herbivore of concern. Its daily intake of grass is expected to be three times its body weight. Thus it should not be stocked in the initial 2-3 years. Other members of the carp family are not herbivores. Once the wetland plants are established, the Grass Carp can be introduced in deeper waters, at low numbers, so as not to destroy the plant leaves of the Primary Lake and Central Wetlands. In addition, cut grass leaves can be a food source for the Grass Carp population in the water body.

(c) Routine Fish Sampling and Restocking

(6) Routine fish sampling is to be conducted to realise the level of fish recruitment and adaptability to a new habitat. Exact density and availability (comprehensive inventory) will not be known at this stage. However, based on the approximate data, some crude idea will be formed which will be suffice to plan a new stocking exercise. The

general aim is to establish a food chain where fish can thrive well without much external feeding and naturally propagate to establish a breeding population. Special emphasis on stocking of Cyprinid species, prawn, *Macrobrachium lancestri* and other invertebates is to be given. The reason is that they form the food of many carnivorous and omnivorous fish species. Care is to be taken so that sampling exercise does not cause problems to ambient water quality, wetland plants and fish stocks. Once established few carp species can be released into main lake and wetlands.

(d) Stocking of Endangered and Rare Species

(7) Stocking of endangered and rare species can be one of the important stocking programmes because the wetland's unique feature and ecological characteristics. The potential species are *Oxyleotris marmoratus*, *Leptobarbus hoevenii*, *Probarbus jullieni* and *Tor tambroides* and *Osphronemus goramy* and *Scalophagus formosus*.

(e) Illegal Fishing

(8) Illegal fishing will be difficult to stop once the wetland system is established when a variety of fish species occupy the productive habitat. Prohibition of illegal fishing can be done by enacting new laws and legislation.

2.7.4.3 Bird Community

(a) Bird Protection

(1) Once the wetland plants and its associated swamp forest are well-established, a diversity of terrestrial and water birds will colonize the habitat. A variety of resident and migratory birds are commonly expected to colonize the habitat. To encourage this, the following steps are to taken:

1. Enact legislation to prohibit bird hunting in any form.
2. Long-term monitoring during the period of migration.
3. The island of Upper Bisa Wetland should have sheltered sites for for birds to graze, perch and roost. Floating rafts anchored to the bottom for

example, can provide nesting and protection from disturbance.

(2) The impact of the birds also need to be monitored to ensure the population numbers and type of birds do not compromise water quality.

(b) Community Awareness and Education

(3) Community awareness and education programme can be undertaken amongst local residents, school and university students and community leaders and other interested groups to encourage public participation in bird watch and their conservation. A warden service needs to be established to provide public liaison and education on water bird watching.

2.7.4.4 Wildlife Community

(1) Undisturbed forest cover is indispensable for animal (wildlife) colonization. Once the vegetation cover of the riparian park (swamp strip) of the wetland is established, wildlife colonization will be widely expected. The following points to be considered for implementation:

1. Enact legislation against wildlife hunting in any form.

2. Increase community awareness and education to prevent poaching, encroachment and hunting.

2.7.5 Flora and Fauna Outside Perbadanan Putrajaya

2.7.5.1 General Condition

(1) Outside the area under Perbadanan Putrajaya, the flora, fauna species found around ponds and waterways are similar to that within Putrajaya. The diversity and abundance of vegetation, fish, avifauna and wildlife community around the Putrajaya lake catchment are one of disturbed types where no pristine forest, game park, bird and wildlife sanctuary were existed. There are no records of unique, endangered or threatened species either plant, fish, avifauna or wildlife reported elsewhere around the vicinity of the lake catchment area.

(2) The fishes introduced into the Putrajaya artificial lake systems are common to aquatic environments of the surrounding areas. Similarly the transplanted aquatic plant species in the wetland systems are generally found in the wetlands and aquatic bodies outside of Putrajaya lake. The inventory of plants, birds and wildlife occurring in the Putrajaya lake and its surrounding areas were recorded in the preliminary EIA report prepared prior to the impoundment of the lake.

2.7.5.2 Flora around Putrajaya

(1) There are about 126 species belonging to 59 Genus and 18 Families recorded in the area outside of Putrajaya Catchment and are shown in Table 2.7.10. The list is by no means a complete and exhaustive one and further field survey may record more species. The species recorded in the EIA study vary in diameter from 5.0 to 20.0 cm. There are no primary forests in areas outside of Putrajaya, however, there are secondary forests.

Table 2.7.10 Flora species

Family	Genus	Species
Myrtaceae	3	17
Lauraceae	4	11
Euphorbiaceae	10	19
Annonaceae	3	3
Anacardiaceae	5	7
Myristicaceae	4	13
Rubiaceae	5	6
Rutaceae	3	5
Leguminosae	1	1
Burseraceae	3	13
Rhizophoraceae	2	3
Flacourtiaceae	4	7
Meuaceae	2	2
Sapindaceae	2	5
Sapotaceae	4	6
Polygalaceae	2	5
Ulmaceae	1	2
Olacaceae	1	1

2.7.5.3 Aquatic Plant Species

There are numerous aquatic plants found in Mardi and UPM ponds, swamps and streams outside of Putrajaya lake catchment area. The common aquatic plants are shown in Table 2.7.11.

2.7.5.4 Fish

The fish species are recorded from the streams and static reservoirs and other water bodies present outside of Putrajaya near UPM and MARDI. They are shown in Table 2.7.12. The list is by no means a complete and exhaustive one and further survey may record more new species.

Table 2.7.11 Aquatic Plant Species around Putrajaya

Scientific Name	Common Name	Status
Lepironia articulata	NA	C
Alstonia spathulata	NA	C
Najas indica	NA	C
Nymphoides indica	NA	C
Ficus microcarpa	NA	C
Cerebra odollam	NA	VC
Pandanus helicopus	Rasau	C
Eleocharis sp.	NA	C
Utricualria sp.	NA	C
Saccharum spontaneum	NA	C
Cyperus sp.	NA	VC
Polygonum barbatum	NA	C
Ludwigia sp	NA	VC
Typha angustifolia	NA	VC
Nelumbo nucifera	Lotus	C
Colocasia gigantea	NA	C
Shorea sp.	NA	C
Eugenia sp.	NA	C

NA - not available; C - common; VC - very common

Table 2.7.12 Fish Species

Scientific Name	Local Name
Oreochromis nilotica	Tilapia
O mossambicus	Tilapia Hitam
Oreochromis sp.	Tilapai Merah
Notopterus chitala	Belida
Clarias batrachus	Keli Kayu
C macrocephalus	Keli Bunga
Mystus sp	Baung
Hampala macrolepidota	Sebarau
Rasbora sp.	Seluang
Puntius sp.	NA
Channa striatus	Haruan
Channa sp.	NA
Trichogaster pectoralis	Sepat Siam

2.7.5.5 Wildlife

The wildlife has been fast depleting in areas outside of Putrajaya because of developmental pressure as more land come under conversion into housing and commercial and other land use schemes. Tables 2.7.13 and 2.7.14 shows the list of wildlife and birds recorded in areas outside of Putrajaya catchment. The list is by no means a complete and exhaustive one and further field survey may record more species present.

Table 2.7.13 Wildlife around Putrajaya

Scientific Name	Local Name	Status
Presbytis obscura	Lotong Chengkong	P
Macaca fascicularis	Kera	P
Cynocephalus variegatus	Kubong	FP
Callosciurus prevostii	Tupai Gading	FP
Tragulus napu	Napuh	P
Ratufa bicolor	Tupai Kerawak Hitam	FP
Presbytis cristata	Lotong Kelabu	P
Helarctos malayamus	Beruang	FP
Tragulus javanicus	Pelandok	P

FP - Fully Protected under Wildlife Act 1972
P - Protected under Wildlife Act 1972

Table 2.7.14 Avifauna

Scientific Name	Local Name	Status
Haliastur indus	Burung Lang	P
Egretta sp.	Burung Pucong	FP
Phylloscopus sp.	Burung Cekup	FP
Pellorneum sp.	Burung Rimba	FP
Pericrocotus flammeus	Mas Belukar	FP
Streptopelia chinensis	NA	P
Halcyon smyrnensis	Burung Pekaka	FP
Amaurornis phoenicurus	NA	FP

NA - Not Available; FP - Fully Protected; P - Protected

2.8 SHORT, MEDIUM AND LONG TERM POLLUTION PROBLEMS

2.8.1 Identification of Pollutants of Concern

2.8.1.1 The major pollutants of concern to the Lake water quality are nutrients, bacteria, and organic chemicals and trace metals which may accumulate in the sediments and flora and fauna.

2.8.1.2 The main nutrient of concern is phosphorous. This enters the water system through non-point and point sources through fertilizer application, detergents containing phosphorous and sewerage waste.

2.8.1.3 The problems faced may be divided into short, medium and long term depending on when in the future the problem may arise and the duration of the problem.

2.8.2 Short Term Problems

The short-term problems are of short duration and may occur any time. They are:

- sediment inflow from construction sites;
- short-circuiting of the wetland function during storm events.

2.8.3 Problems in the Medium Term

The medium term problems will be of importance in the middle future (2-5 years) and can result in problems lasting a few years (2-10 years) if not controlled. For example, lack of control of short term problems of soil erosion may lead to medium term problems of lake sedimentation. The medium term problems are:

- the high (>2,000 counts/100 ml) of faecal coliform;
- sediment inflow from construction sites;
- possible short-circuiting of the wetland function during storm events.

2.8.4 Problems in the Long Term

2.8.4.1 In the long term (>10 years), the problem will be accumulation of

- trace metals, for example mercury, as indicated by the high concentrations in the baseline data
- sediments in the wetlands;
- phosphorus in the sediments.

2.8.4.2 In addition as the wetland system progresses in its natural development and growth, euthrophication will become a problem.

2.8.4.3 Organic chemicals from pesticides and herbicides may be detected by monitoring and their use controlled within the catchment.

2.8.4.4 For metals, accumulation will occur in the sediments and their sources may be more difficult to trace. Fertlizers may be a source of trace metals as are roads and stormwater.

2.9 TECHNICAL AND MANAGEMENT MEASURES

2.9.1 Point sources

2.9.1.1 Central Sewage Treatment Systems

(1) The model results indicate that a Total Phosphorus loading of 2 mg/l at design discharge will be the uppermost concentration which could be handled by the model to ensure a Lake target value of 0.05 mg/l.

(2) Therefore, Sewage Treatment systems which could produce an effluent of this concentration would be recommended for the catchment.

(3) Within the Kawasan Perbadanan Putrajaya, however, there are the recommendations for Parameter Limits of Effluent discharged into any waterways or land (Appendix 18 of the Putrajaya Environmental Management Guide). The limits for Total Phosphate here is 0.05 mg/L.

(4) Within the Kawasan Perbadanan Putrajaya, most discharges will not have the benefit of having wetlands to ameliorate the effects of discharges to the Lake. The Lake model indicates also that runoff flow and flow entering the Lake without the benefit of wetlands can greatly affect the Lake phosphorus level. Thus the standards for effluent discharged are much stricter.

(5) In addition the following recommendations are made to the Parameter Limits of Effluent:

- The parameter limits for Faecal Coliform should be reduced from 2000 counts/mL to 200 counts/100 mL by 1 January 2002.

- The parameter limits for Total Coliform should reduce from 10000 to 5000 counts/mL by 1 January 2002.

2.9.1.2 Septic Tank Systems

(1) There are several septic tank systems already existing in the catchment in IOI, MARDI and UPM.

(2) The effluent from these systems need to be co-ordinated into the recommended UPM-MARDI sewage treatment facility

prior to discharging into the Upper-West or Upper-North wetlands.

(3) There are expected to be several more systems in Sg Merab. The plans for these areas are unclear at present. Considering the small area involved and the expected low-density of future development, Perbadanan Putrajaya should consider incorporating the wastewater from these areas into their central sewage system.

(4) Considering the small area involved and the expected low-density of future development, Perbadanan Putrajaya should consider incorporating the wastewater from these areas into their central sewage system.

2.9.2 Non-point sources

2.9.2.1 Land Design

(1) The concept of "core zone" in land use design is the main principle in developing conservation areas. The central core is considered most sensitive and is most protected from development. This is fringed by an intermediate buffer zone of low intensity use with increasing intensity use located in the outer fringe to the central core.

(2) Within the catchment, the wetlands and natural streams may be considered the most sensitive. Therefore,

- riparian management zones or buffer strips (see below) of 30 to 10 m width on each side should be maintained;

- higher intensity development should be located further away from the water courses.

2.9.2.2 Best Management Practices

(1) Management of non-point pollutant input into waters is normally carried out by different management practices based on observations, experimentation and experience. Generally the best management practices for pollutant reduction tries to mimic the natural environment which has been disturbed by man. Thus the more natural-looking an environment the less likely is the pollutant input that might be expected.

(2) Based on such premise, therefore, there should be as much an abundance of vegetation as possible without it being detrimental to human activities. Within the Putrajaya Lake Catchment the best example of this enforced 'naturalness' is the Sungai Kuyoh sub-catchment in MARDI. Here the streams and ponds are line with tall grasses and trees. What might be regarded as an overgrowth of grasses in the streams actually serve multiple functions.

(3) They

- increase channel, reduce flow velocity, and carrying erosive or load carrying capacity;
- trap particulates, and encourage sedimentation;
- reduce sunlight penetration in the water column, discouraging algal growth, even in excess of nutrients;
- uptake nutrients in the water column and store in plant materials;
- provide stable habitats for aquatic ecological systems.

(4) The development of the Putrajaya Catchment area therefore should try to simulate such stream or riparian environments along the natural water courses, ponds and even storm drains. Riparian Management Zones (RMZ) should be established following the practice in forestry management. The guidelines for buffer zone widths based on land slope is given in Appendix D.

2.9.2.3 Recreational and Fish Ponds

There are a number of recreational and fish ponds in the MARDI ands UPM area. Figure 2.9.1 to 2.9.6 shows the landscape of some of these ponds. They serve a useful function in terms of preserving the water quality.

2.9.2.4 Guidelines for the Development of Mini-Wetlands

(1) Wetlands should be shallow whereas detention ponds are deep. For the detention ponds that have been identified as possible to function also as mini-wetlands, a number of factors are to be considered. In particular, ponds which drain directly into the Putrajaya Lake should have longer retention times compared to those ponds draining into one of the six wetlands. The

Figure 2.9.1 Small waterfall at the top of Sg. Kuyoh, MARDI. It can form part of mini wetlands of Sg. Kuyoh catchment.

Figure 2.9.2 Small waterfall at the top of Sg. Kuyoh, MARDI. It can form parf of mini-wetlands of Sg. Kuyoh catchment

Figure 2.9.3

Large man-made Reservoir in MARDI. There is continuous water supply from the upstream water fall. With Planting of wetland plants along its edge, it can serve to sequester pollutants and nutrients.

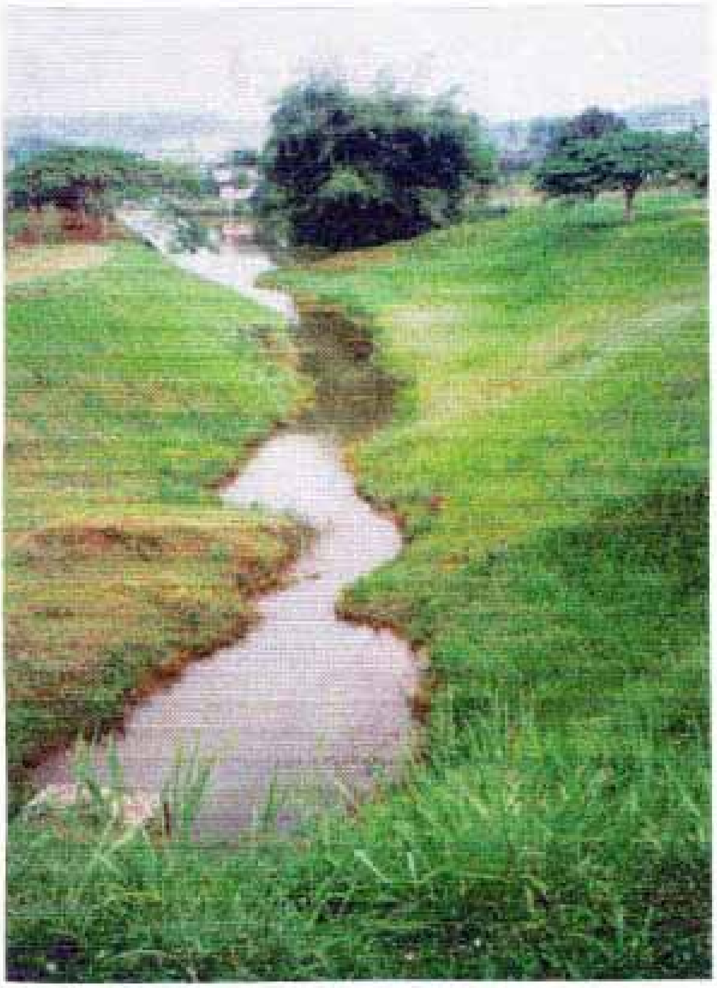


Figure 2.9.4

Overflow water from the MARDI Reservoir (Figure 2.9.3) enters into Sg. Kuyoh and finally discharge into Upper West Wetland.

Figure 2.9.5 Existing UPM Pond at the upstream of upper North Wetland. Lotus *Nelumba Sucifera* can form a cover mat on the water surface to reduce plankton biomass in the water. The Rhizome system can help uptake of nutrients. The future mini-wetland may have lotus in the open water.

Figure 2.9.6 Wetlands plants along the banks overhang the stream.

retention times for the latter can be shorter because of the additional retention time and thus treatment capacity in the downstream wetlands.

(2) Mini-wetlands are intended as public open spaces but the public should have limited access to them to ensure ecological preservation. By virtue of limited access, the wetland will become a refuge for nature.

(3) The selection of plants to be planted in the wetlands and the use of agricides must follow the regulations governed by the Plant Quarantine Act 1976 (Act 167), and the Pesticide Act.

(4) The function and usefulness of mini-wetlands are almost the same as for riparian parks, lake valley parks and retention ponds to be provided within the Putrajaya Federal Government Administrative Centre Peripheral areas (refer to Urban Design Analysis and Strategy). Nonetheless, there will be differences in the physical shape, size and depth of mini-wetlands with those of parks and retention ponds proposed in the Urban Design Masterplan. Despite these physical spatial differences, the basis of species selection and planting strategy at various zones of wetlands will be based on the guidelines spelt out in the Urban Design Masterplan.

(5) Additional guidelines for the development of mini-wetlands are given in Appendix C.

2.9.2.5 Gross Pollutant Trap

(1) Gross pollutant traps (GPTs) act to trap litter and sediment. Since much nutrients are adsorbed onto sediments it is expected that sediment trapping will also result in nutrient trapping. Previous model studies making such assumptions on nutrient-sediment relationships have been carried out by Angkasa GHD in the Putrajaya Drainage Master Plan Study Report (1996). The data present there is given in Table 2.9.2 along with the net removal efficiencies predicted by their model. Nevertheless, the Report also cautioned that such assumptions are ‘tenuous’.

(2) Based on stream environment and the proposed developments in the catchment, GPTs are only required for areas of substantial drainage modification and build up. The GPT locations proposed are indicated in the Catchment Drainage Masterplan.

2.10 SUMMARY

2.10.1 In order to fulfil the role and function of the Lake for Putrajaya, we must control the **water quality**.

2.10.2 In the ideal condition, the desired Lake conditions would determine the needs for the wetlands and the catchment development. The original design for the Lake and wetlands adopted this approach.

2.10.3 After construction of the Lake and wetlands, we need to consider the reality of the situation and look at the response and interactions between the Lake and the wetlands and the wetlands with the catchment.

2.10.4 This is essentially a matter of :

LAND ←→ WATER
interaction

2.10.5 In addition we need to recognize that the definition of pollutants are things which are **not wanted**, and that even natural chemicals, flora and fauna may be considered to be polluting to the Lake system.

2.10.6 The different factors affecting the Lake system are a complex interplay of hydraulic, biological and chemical aspects. In the study, this complex system is simplified in order to model the factors which may affect the Lake behaviour. We hope that the model results can provide an understanding of the system so that recommendations may be made on the management of the whole catchment development.

Table 2.9.2 Modelled GPT (with treatment) sediment and nutrient removal efficiency in Perbadanan Putrajaya
(from Perbadanan Putrajaya Drainage Masterplan Study Report, 1996)

Water Quality Parameter		Lake		Wetland		Offsite	
		t/a	mg/L	t/a	mg/L	t/a	mg/L
Government Precinct							
Suspended Solids	No Treatment	1260	231	300	173	-	-
	With Treatment	760	139	180	104	-	-
	Removal Efficiency %	39.7	39.83	40.00	39.88	-	-
Total Phosphorus	No Treatment	2.6	0.5	0.7	0.4	-	-
	With Treatment	1.8	0.3	0.5	0.3	-	-
	Removal Efficiency %	30.77	40.00	28.57	25.00	-	-
Total Nitrogen	No Treatment	8.1	1.5	3.2	1.8	-	-
	With Treatment	5.7	1	2.2	1.3	-	-
	Removal Efficiency %	29.6	33.3	31.3	27.8	-	-
CBD Precinct							
Suspended Solids	No Treatment	1000	155	-	-	-	-
	With Treatment	600	93	-	-	-	-
	Removal Efficiency %	40.0	40.0	-	-	-	-
Total Phosphorus	No Treatment	2.4	0.4	-	-	-	-
	With Treatment	1.7	0.3	-	-	-	-
	Removal Efficiency %	29.17	25.00	-	-	-	-
Total Nitrogen	No Treatment	10	1.6	-	-	-	-
	With Treatment	7	1.1	-	-	-	-
	Removal Efficiency %	30.00	31.25	-	-	-	-
Residential Precinct							
Suspended Solids	No Treatment	1870	124	330	135	1850	160
	With Treatment	1120	74	200	82	1110	96
	Removal Efficiency %	40.1	40.3	39.4	39.3	40.0	40.0
	No Treatment	4.3	0.3	0.7	0.3	4.4	0.4

Water Quality Parameter		Lake		Wetland		Offsite	
		t/a	mg/L	t/a	mg/L	t/a	mg/L
Total Phosphorus	With Treatment	3	0.2	0.5	0.2	2.6	0.2
	Removal Efficiency	30.23	33.33	28.57	33.33	40.91	50.00
Total Nitrogen	No Treatment	18.2	1.2	3.7	1.5	20.9	1.8
	With Treatment	12.8	0.9	2.6	1.1	9.8	0.8
	Removal Efficiency %	29.7	25.0	29.7	26.7	53.1	55.6
Sport & Recreation Precinct.							
Suspended Solids	No Treatment	430	148	-	-	340	146
	With Treatment	260	90	-	-	210	90
	Removal Efficiency %	39.53	39.19	-	-	38.24	38.36
Total Phosphorus	No Treatment	1	0.3	-	-	0.8	0.3
	With Treatment	0.7	0.2	-	-	0.5	0.2
	Removal Efficiency %	30.00	33.33	-	-	37.50	33.33
Total Nitrogen	No Treatment	4.2	1.4	-	-	3	1.3
	With Treatment	2.9	1	-	-	1.7	0.7
	Removal Efficiency %	30.95	28.57	-	-	43.33	46.15

2.10.7 In the Land-Water system, the LAND Components are the different sub-Catchments.

1. Upper North
2. Upper West
3. Upper East
4. Lower East
5. Upper Bisa
6. Central Sg Chuau
7. Lower Sg Chuau
8. Captured Sg Limau Manis

2.10.8 The current and future pollutant potential assessment is presented in Section 2.5, along with recommendations to control point and nonpoint pollutant.

2.10.9 In general, for areas outside Putrajaya, there is a need to:

- upgrade sewage treatment facilities,
- control the pesticide and fertilizer use,
- develop riparian buffer strips or management zones along streams,
- utilisation/development of existing and proposed ponds as mini-wetlands.

2.10.10 The WATER components are the Water and Biota.

2.10.11 Water quality data were reviewed and additional measurements were made for purpose of model calibration (Section 2.6).

2.10.12 At the Temporary Dam Stilling Basin (Table 2.6.6),

- DO is low
- BOD is low
- NO_3 is low
- TP is at or slightly above Ambient Level
- Coliform count is high

2.10.13 From the water quality data and field observations, it is observed that:

- the pattern between top and bottom cells is not simple, reduction as well as increases occur (from -167% to 94% change);
- this is not expected, therefore we speculate that other source inputs, such as lateral inflows, internal resuspension or introduction, may occur.

2.10.14 In the Water Quality Modelling (Section 2.6.3) section the purpose was:

- to estimate capacity of Wetlands and Lake to treat pollutants;
- to predict behaviour of water quality conditions under different scenarios of rainfall and pollutant inputs; and
- to understand factors influencing water quality conditions.

2.10.15 The model used was the MIKE 11 software. This includes hydrodynamic, advection-dispersion, and water quality modules. The model was calibrated for water processes for a normal rainfall (2.2 m) year (1984) to the monitored data of this study. The model results tend to lie in lower range of observed monitored data.

2.10.16 The major parameter of concern is Phosphorus. The modelled parameters were Available Dissolved OrthoPhosphorus and Particulate Phosphorus. The scenarios and results are summarized below.

2.10.17 Scenario 1 - for current TP Pollutant loading from Top, compared to reduced, low TP loading from Top, Same Lateral inflow loading

Results

in wetlands

- low loading slightly better water quality

in Central Wetland

- water quality almost same

in Lake

water quality almost same

➔ Lateral Inflows to system are important

2.10.18 Scenario 2 - for dry (1.6 m) and wet (2.7 m) year, coincides with lower and higher pollutant loading respectively (constant low concentration).

Results

wet year slightly worse water quality

dry

year very slightly better water quality

➔ increased flow in wet year may short-circuit processes

2.10.19 An assessment of the wetland vegetation was also carried out. The vegetation within the wetland cells are expected to provide an ecosystem where nutrient input may be utilised for growth and thus removed from the water column.

2.10.20 The current conditions in the wetlands are presented in Section 2.7.

2.10.21 The observations indicated that both vegetation and aquatic fauna, i.e. fish, will need to be managed in future. The issues to be addressed are:

- plant growth patterns - density and distribution of species,
- weed overgrowth,
- disease and pest infestation,
- water levels management,
- fish community distribution - overpopulation of dominant fish species will be undesirable ecologically, and must be controlled,
- birds and wildlife population number appropriate for the system.

2.10.22 Monitoring measures need to be implemented for:

- vegetation
- fish
- birds and other wildlife

2.10.23 Investigative and research studies need to be carried out on the vegetation communities and their appropriate structure within the Wetlands as well as along the Lake shoreline.

2.10.24 Their effectiveness in

- improving water quality,
- enhancing ecological habitat, and
- ease of maintenance,

are among the factors to be considered.

2.11 RECOMMENDATIONS

2.11.1 Catchment Management and Development

2.11.1.1 Catchment management and development entails that planning be carried out on a catchment basis, following the drainage pattern.

2.11.1.2 The catchment area of Putrajaya Lake comprises of eight major sub-catchments:

- Upper-North,
- Upper-West,
- Upper-East,
- Lower-East,
- Bisa,
- Central,
- Lower, and
- Limau Manis.

2.11.1.3 Comments on the current and potential future development in these sub-catchments for the area outside of Kawasan Putrajaya have been discussed in section 2.5 above and recommendations have been made.

2.11.1.4 The approach of sensitive central core is an appropriate concept in the landuse planning of the area. It allows for the introduction of development in a gradual manner, increasing away from the sensitive zones.

2.11.1.5 The application of softscape designs, such as a riparian management zone (RMZ), especially for natural streams will greatly alleviate the problems of non-point source pollution from overland flow. The riparian zones are planted with

- trees, for shade, and to provide organic detritus for ecosystem development;

- shrubs, to provide prevent incursion across the riparian area, provide bird habitat, and uptake nutrients from the root zone; and

- long grasses, to streamline overland flow, reduce flow velocity, precipitate sediment and capture trash.

2.11.1.6 For point source pollution, centralisation of waste facilities will reduce loadings to levels which can be handled by the wetland systems introduced. In addition the utilisation of existing or future detention ponds will allow for dispersed treatment of point and non-point pollutants prior to discharge into the Putrajaya Wetlands.

2.11.1.7 Monitoring of chemical usage through a register will allow for ease in control and management to prevent possible future problems and allow for assessment of land and buffer zoning measures.

2.11.1.8 In particular the following steps should be taken:

1. Control of lateral surface runoff inflow into the Lake and Wetlands is imperative;

2. Land management measures, such as introduction of vegetated buffer strips, cover of exposed soil, must be carried out;

3. Lake Water and Biological Quality Monitoring, including Discharge monitoring along streams and stormwater outlets, such as recommended in the Lake Management Guide must be implemented;

4. Investigative Monitoring needs to be initiated, aside from standard monitoring, in order to understand the processes occurring within the Wetlands and Lake. The parameters of relevance are Phosphorus (dissolved and particulate), Chlorophyll *a*, Secchi depth, Coliform, Nitrogen (nitrate and ammonia), Dissolved Oxygen. Surface and depth sampling along and across the water bodies and within vegetated areas.

5. Given that the Wetlands and Lake now exist, and the knowledge gained from this study, a detailed assessment of the existing and expected future condition of each Wetland cell and each portion of the Lake would need to be carried out. This is to determine the behaviour of the system and the appropriateness and availability of facilities and infrastructure to control and manage the hydraulic and biological conditions. The behaviour of the vegetation systems, their effectiveness and suitability for the system need to be researched.

Such information will contribute towards better implementation of the development of mini-wetlands, buffer strips, and other land measures, and towards a more effective plan for the management of the Catchment.

6. As the areas around the catchment are still under development, it is important to ensure effective control of erosion and sediment during earthworks and construction activities. It is recommended that a new "Erosion and Sediment Control By Law" be enacted by the Perbadanan Putrajaya and Majlis Daerah Sepang. The recommended By-Laws should be supported by a new manual on "Procedural Standards for Erosion and Sediment Control" which would detail the specifications and design of erosion and sediment control measures and works.

7. The best management practices and guidelines in this report, especially as outlined in Appendices A, B, C, and D, should be made conditions of approval for permission to commence with the project development plan (kelulusan merancang pelan susun atur) within Putrajaya as well as in the Local Plans of the areas within the Putrajaya Lake catchment.

8. A full report on the present status of the wetlands and Lake needs to be prepared to provide the basis for comparison of future change. The report should form the baseline to assess cumulative effects as well as to understand the changes to the Phase 1A Lake prior to Phase 1B being flooded.

9. There is also a need to outline the possible technical and engineering controls that may be implemented to support the management of the wetland system. In addition to the Lake and Wetland Operation Manual there should be consideration of flow inducement, vertical mixing of the water column, weir technology, mechanical systems for wetland management, chemical treatments for phosphorus fixing, sediment removal, as well as possible design modifications.

2.11.2 Monitoring

2.11.2.1 Biological Monitoring

(1) There should be at least quarterly reports on the status of wetland, their efficiency, their input and outputs as well as on water levels. The use of chemicals, their types and quantities applied in the wetlands and lake area must be recorded and reported, for example, for pesticides via the Pesticide Register. The application of fertilizers should follow the guidelines issued by the Department of Agriculture for crop plants.

(2) The details of biological monitoring of vegetation is outlined in the Perbadanan Putrajaya Lake Management Guide and is suitable for application for the mini-wetland areas.

(3) Fish stocks need only be assessed twice a year by sampling through various fishing methods: hook and line, nets, and catch-effort in hours spent. The routine fish sampling recommended previously will provide input for this twice annual assessment.

(4) Wildlife sampling, either through tagging of animals and subsequent trapping or by visual observation and counting, should be carried out seasonally, particularly for birds. This would mean observations in March-April and September-October.

(5) The mini-wetlands maintenance managers for outside of the Perbadanan Putrajaya area should prepare reports on the wetland status, efficiency and maintenance programme at least once every three months. Information on each mini-wetland is to be available. Within Putrajaya the Lake and Wetlands Management Unit should prepare or have a maintenance contractor prepare, the reports for each wetland cell, the Riparian Parks and the Detention Ponds.

2.11.2.2 Water Quality Monitoring

(1) Water quality monitoring for the catchment area outside of Putrajaya is proposed to be on

- a self-monitoring basis in the form of monthly reports on sewage effluent quality and treatment plant efficiency by the plant operators. The Sewage Masterplan section deals with this programme;

- mutual data exchange basis for natural stream flows. The monitoring programme which has been proposed for Perbadanan Putrajaya already includes monitoring of cross-boundary water flow at the different wetlands and at the Cyberjaya border on the Lake. These points represent the effectiveness of non-point source pollutant control measures which will be implemented by the different stakeholders.

(2) Within Perbadanan Putrajaya, the Lake Management Guide provides information on the monitoring programme to be carried out.

(3) The specific water quality parameters of importance are suspended **sediment, Dissolved Phosphorus (Ortho-phosphate), Total Phosphate, and Chlorophylla**. The effect of the three parameters may be estimated by using the **Secchi disk reading**. The Secchi disk reading can be related to the three parameters mentioned by regression analysis. In addition the three parameters may be used to calculate the Carlson Index as outlined in the Lake Management Guide. Investigative monitoring of the three parameters for at least one month on a daily basis should be sufficient to form the basis for the correlation. The monitoring should preferably be repeated at different hydrological/meteorological seasons to take into account flushing rates in the Lake.

(4) The present Putrajaya Lake ambient water quality level for the Secchi disk reading is 0.6 m. As a guide, an observed reading of less than 0.3 m in the Lake will indicate that one, or the combination of the three parameters is reaching undesirable concentrations. Sources of the pollutants should then be sought and some measure of control, e.g. turfing, silt trap maintenance or effluent regulation will need to be implemented on sediment and phosphorus release.

(5) It is expected that in future the ambient Secchi Disk level can be increased depending on observations in the Lake. Possibly a level of 1.0 m may be adopted at the end of 2001 and that a level of 2.5 m might be adopted in 2003.

2.11.3 Special issues

A few specific issues need immediate attention, however. They are

1. the planning, construction, control, and operation of the transport lines crossing the Upper-West and Upper-North Wetlands;

2. the designation of a special habitat area for birds (section 2.9.2.5c) located at the top of the Upper-West Wetland buffer area and north of the proposed B11 highway;

3. the need to develop the promenade area, including the Cyberjaya promenade, and GPTs in the Lake shore between the temporary Dam and Main Dam prior to closure of the Main Dam;

4. revision of landscaping of the shoreline bordering natural streams and wetlands to conform to riparian management zone functions.

2.12 REFERENCES

1. Alfred, E.R. (1964), Some colourful fishes of the Geneus *Puntius H*amilton,Bull. Nat. Mus. Singapore, Vol. # 32, pp.# 135-142

2. Angkasa GHD Engineers Sdn. Bhd., GHD Pty. Ltd. (1996), Putrajaya Lake Phase 1 Concept Design Report Wetland Component, August 1996. PJ Holdings Sdn. Bhd.

3. Corner, E.J.H. (1978), The freshwater swamp of South Johor and Singapore. Gardens Bulltin Suppl. No. 1, 266 pp

4. Holttum, R.E. (1954), A revised flora of Malaya, Vol. # 1, Orchids, Vol. 2 Ferns. Government Printing Office, Singapore

5. Idris, M.S & Rozaina, Z. (1992), An updated list of wetland plant species of Peninsular Malaysia with particular reference to those having socio-economic value. AWB Publication No. 79, 103 pp.

6. Inger, R.F & Chin, P.K. (1962), The freshwater fishes of North Borneo, Fieldiana Zool. Vol. # 45, pp. 1-268

7. IUCN (1994), IUCN red list categories. Gland, Switzerland: IUCN

8. Kumpulan Perunding Kota Bistari Sdn. Bhd. (1996), Water Quality Management Control and Mangement Study Report, Draft Final report, February 1996. Putrajaya Lake Development. Putrajaya Holdings Sdn Bhd.

9. Mohsin, A.K.M. & Ambak, M.A. (1982), Freshwater fishes of Peninsular Malaysia. UPM Publication. 283pp

10. Ng, F.S.P. (1978), Tree Flora of Malaya, Vol.# 3, Forest Department, Ministry of Primary Industries, 339 pp.

11. Ng, P.K.L., Tay, J.B., Lim, K.K.P. and Yang, C.M. (1992), The conservation of fish and other aquatic fauna of North Selangor Peat Swamp Forest and adjacent areas. AWB Publication # 81, 90 pp, KL Malaysia.

12. Pancho, J. & Soejani, M. (1978), Aquatic weeds of South-East Asis. National Publishing Cooperatives, Quezon City, 109 pp.

13. Ridley, H.N. (1922-1925), The flora of Malay Peninsula, Vol. # 1-5, Reeve, London.

14. Whitmore, T.C. (1988), Forest types and forest zonation. Key environments Malaysia. IUCN, Pergamon Press, pp # 20-30.

15. Wyatt-Smith, J. & Kochumen, K.M. (1979), Pocket check list of timber trees. Malayan Forest Records # 17, Forest Department, Peninsular Malaysia. 362 pp.

APPENDIX 2.1
PUTRAJAYA WATER QUALITY DATA AS MONITORED BY UPM

Date:30.8.99

	UN8	UN1	UW7	UW1	UE3	UE1	LE2	LE1	CW	Dam
DO	6.2	4.4	6.8	9.4	3.2	8.2	6.4	4.4	7.8	-
BOD	3.93	0.79	0.47	1.10	0.41	0.85	1.46	1.33	2.00	-
NO3	0.8	0.4	0.4	0.7	0.6	0.3	0.2	0.6	0.8	-
TP	0.31	0.07	0.11	0.09	0.07	0.07	1.76	0.33	0.31	-
Dis.P	0.29	0.04	0.09	0.05	0.07	0.03	1.46	0.05	0.09	-
Par.P	0.02	0.03	0.02	0.04	0	0.04	0.30	0.28	0.22	
Turbidity,NTU	6.49	0.99	9.24	0.07	14.75	1.90	5.57	0.07	4.66	-
Ecoli	5000	0	10000	0	0	0	0	0	0	-
Tcoli	10000	0	25000	0	2000	0	0	5000	1000	-

Date:6.9.99

	UN8	UN1	UW7	UW1	UE3	UE1	LE2	LE1	CW	Dam
DO	3.0	3.5	4.2	4.8	3.4	4.6	0.6	4.8	7.0	4.0
BOD	3.45	0.69	0.14	0.68	0.16	0.49	2.19	0.40	1.16	1.09
NO3	0.9	0.8	0.7	0.5	0.1	0.8	0.2	1.4	0.4	1.1
TP	4.36	8.53	1.53	3.66	2.73	1.16	0.77	1.86	0.37	0.34
Dis.P	2.4	3.16	1.13	3.0	1.26	0.86	0.65	1.5	0.32	0.27
Par.P	1.96	5.37	0.40	0.66	1.47	0.3	0.12	0.36	0.05	0.07
Turbidity,NTU	15.67	7.41	13.83	6.49	23.00	8.33	29.43	4.66	4.66	8.33
Ecoli	10000	10000	20000	10000	20000	1000	0	2000	7000	4000
Tcoli	15000	12000	25000	25000	30000	5000	5000	14000	10000	0

Date:8.9.99

	UN8	UN1	UW7	UW1	UE3	UE1	LE2	LE1	CW	Dam
DO	1.8	2.9	2.2	3.6	2.6	4.0	3.8	4.6	-	4.2
BOD	4.04	0.06	1.86	0.73	0.35	0.79	0.52	0.56	-	0.41
NO3	0.9	0.7	0.8	0.7	0	0.5	0.8	0.9	-	0.7
TP	0.35	0.08	0.15	0.07	0.06	0.08	0.40	0.85	-	0.57
Dis.P	0.17	0.03	0.05	0.03	0.02	0.04	0.03	0.04	-	0.01
Par.P	0.18	0.05	0.10	0.04	0.04	0.04	0.37	0.81	-	0.56
Turbidity,NTU	17.5	12.0	75.3	6.49	27.59	9.24	6.49	4.66	-	7.41
Ecoli	1200	100	1000	6000	300	200	0	300	-	2000
Tcoli	8000	1500	3000	16000	2000	900	1000	1200	-	5000

Date:10.9.99

	UN8	UN1	UW7	UW1	UE3	UE1	LE2	LE1	CW	Dam
DO	1.8	3.2	2.4	3.3	2.0	2.8	2.2	4.0	3.4	2.8
BOD	5.46	0.87	1.51	1.17	0.58	0.68	2.56	0.65	1.49	1.89
NO3	0.8	0.2	0	0.6	0	0.2	0	0.4	0.4	0.5
TP	0.44	0.13	0.18	0.16	0.18	0.13	0.17	0.10	0.11	0.15
Dis.P	0.29	0.06	0.11	0.06	0.08	0.05	0.12	0.05	0.05	0.05
Par.P	0.15	0.07	0.07	0.1	0.1	0.08	0.05	0.05	0.06	0.1
Turbidity,NTU	15.67	14.75	24.84	9.24	35.85	10.16	23.01	9.24	8.33	19.34
Ecoli	10000	15000	5000	600	5000	2000	0	0	1500	3000
Tcoli	15000	20000	12000	4000	12000	5000	1000	600	3100	5000

Date:13.9.99

	UN8	UN1	UW7	UW1	UE3	UE1	LE2	LE1	CW	Dam
DO	1.8	2.6	2.0	2.8	3.4	2.0	2.0	3.8	3.2	-
BOD	7.5	0.93	1.29	0.76	0.68	0.90	2.53	0.66	0.90	-
NO3	5.1	0.4	0.1	0.2	2.3	0.2	0.5	0.5	0.7	-
TP	0.32	0.21	0.12	0.05	0.04	0.09	0.64	0.04	0.05	-
Dis.P	0.09	0.15	0.07	0.04	0.04	0.08	0.61	0.02	0.03	-
Par.P	0.23	0.06	0.05	0.01	0	0.01	0.03	0.02	0.02	-
Turbidity,NTU	13.83	3.74	12.0	5.57	9.24	31.26	45.94	0.07	4.66	-
Ecoli	800	0	400	0	500	600	200	0	200	-
Tcoli	2500	1500	2500	2000	20000	3200	2500	400	1000	-

I. Date:15.9.99

	UN8	UN1	UW7	UW1	UE3	UE1	LE2	LE1	CW	Dam
DO	1.8	2.8	2.4	2.8	2.0	3.2	1.8	3.6	3.5	3.8
BOD	2.5	0.58	0.17	0.96	0.75	0.7	1.02	1.07	1.0	1.3
NO3	2.1	0.4	0.6	1.6	1.1	0.5	0	1.5	0.9	2.8
TP	0.1	0.11	0.1	0.08	0.08	0.12	0.07	0.14	0.05	0.07
Dis.P	0.06	0.04	0.06	0.05	0.04	0.09	0.03	0.06	0.04	0.04
Par.P	0.04	0.07	0.04	0.03	0.04	0.03	0.04	0.08	0.01	0.03
Turbidity,NTU	39.52	23.01	14.75	32.18	45.03	11.08	49.61	3.74	6.49	9.24
Ecoli	1000	100	300	100	200	100	0	200	0	200
Tcoli	2500	500	1200	300	400	400	300	1000	2200	400

Date:17.9.99

	UN8	UN1	UW7	UW1	UE3	UE1	LE2	LE1	CW	Dam
DO	2.2	2.4	2.2	2.4	2.2	3.2	1.2	4.6	4.0	3.6
BOD	4.32	1.14	1.01	0.84	1.63	0.81	0.64	4.46	1.26	1.63
NO3	0.2	1.5	4.4	2.9	5.2	1.8	7.6	3.1	2.9	2.9
TP	0.14	0.08	0.55	0.08	0.04	0.11	0.5	0.1	0.09	0.1
Dis.P	0.05	0.05	0.4	0.06	0.03	0.08	0.14	0.09	0.06	0.05
Par.P	0.09	0.03	0.15	0.02	0.01	0.03	0.44	0.01	0.03	0.05
Turbidity,NTU	34.93	18.42	202.84	6.49	124.85	12.91	140.45	4.66	7.41	26.68
Ecoli	2000	1200	1400	0	2200	100	2000	0	200	400
Tcoli	7000	2500	4000	1000	3200	600	2500	1500	2200	700

APPENDIX 2.2
PUTRAJAYA WATER QUALITY DATA FOR EACH CELL AS MONITORED BY UPM

Upper North Wetland
Date: 22.9.99

	UN8	UN7	UN6	UN5	UN4	UN3	UN2	UN1
DO	2.0	2.8	3.4	2.6	2.4	3.0	1.8	2.6
BOD	3.56	3.1	1.42	0.57	0.50	0.17	0.25	0.11
NO3	1.1	0.9	1.4	1.3	1.0	0.7	1.8	0.9
TP	0.04	0.03	0.04	0.04	0.04	0.02	0.02	0.02
Dis.P	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.01
Par.P	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
Turbidity, NTU	20.25	29.43	10.16	25.76	11.08	10.16	11.08	13.83
Ecoli	3000	200	0	0	100	1200	0	0
Tcoli	4000	900	500	800	1000	200	500	700

Upper West Wetland
Date:24.9.99

	UW7	UW6	UW5	UW4	UW3	UW2	UW8	UW1
DO	2.2	2.0	2.2	2.6	2.8	2.6	3.2	2.8
BOD	2.12	0.98	1.57	1.22	2.92	1.56	1.66	1.88
NO3	0	0.4	0	0.5	0.6	0.4	0.3	0.6
TP	0.1	0.01	0.02	0.08	0.04	0.05	0.08	0.03
Dis.P	0.03	0	0	0.02	0	0.02	0.02	0.01
Par.P	0.07	0.01	0.02	0.06	0.04	0.03	0.06	0.02
Turbidity,NTU	405.6	19.3	28.5	7.4	7.4	10.1	17.0	4.0
Ecoli	2500	100	1000	200	300	0	500	0
Tcoli	3500	200	2000	700	800	500	2800	300

Upper East and Lower East Wetland
Date:24.9.99

	UE3	UE2	UE1	LE2	LE1	CW	DAM
DO	2.2	2.2	3.3	3.2	3.8	3.8	4.0
BOD	0.48	0.39	0.25	0.31	0.49	0.93	0.85
NO3	0	0	0.5	0.5	0.4	1.0	1.0
TP	0.41	0.11	0.02	0.05	0.06	0.01	0.04
Dis.P	0.34	0.09	0.01	0.02	0.04	0	0.01
Par.P	0.07	0.02	0.01	0.03	0.02	0.01	0.03
Turbidity,NTU	39	6	5	15	1	4	2
Ecoli	0	100	200	0	0	0	100
Tcoli	2000	600	600	700	1000	500	5000

APPENDIX 2.3
PUTRAJAYA WATER QUALITY DATA AS MONITORED BY UPM

a. Upstream Sg Chuau from UPM side entering MARDI

	U0	U10	U30	U100	U150
Distance, m	0	10	30	100	150
DO	0.6	0.4	0.4	0.5	2.0
BOD	12.75	9.7	11.7	13.75	7.35
NO3	0.6	1.0	0.8	0.9	0.9
TP	5.0	3.6	2.8	3.4	3.7
Dis.P	0.8	0.9	1.1	1.2	1.1
Par.P	4.2	2.7	1.7	2.2	2.6
Turbidity, NTU	0.99	1.90	2.82	12.91	0.07
Ecoli	10000	15000	15000	20000	12500
Tcoli	15000	20000	20000	25000	20000

b. Downstream Sg Chuau from MARDI entering UPM

	M0	M50	M110	M210	M310	M410	M440
Distance, m	0	50	110	210	310	410	440
DO	0.4	0.2	0.6	0.8	1.0	1.8	1.8
BOD	18.42	17.07	17.52	17.61	17.49	14.64	12.99
NO3	0.6	2.3	1.3	2.8	2.7	1.4	1.3
TP	8.5	6.4	7.7	6.0	4.2	5.1	4.6
Dis.P	8.0	6.3	7.1	4.6	3.4	4.2	4.0
Par.P	0.5	0.1	0.6	1.4	0.8	0.9	0.6
Turbidity,NTU	34.93	32.18	30.35	32.18	18.42	17.5	12.0
E. Coli	20000	30000	25000	15000	25000	20000	20000
Total Coli	25000	40000	30000	20000	30000	25000	25000

APPENDIX 2.4
PRELIMINARY MODEL SIMULATIONS

1.0 Preliminary Model simulation and performance

Model runs were carried out to compare removal efficiencies in the wetlands. Three scenarios were *simulated*:

a) with design inflow and ambient water quality parameter;
b) with high hydraulic loading and
c) with high concentrated loading.

The run-off scenario with the expected pollutant from each landuse area will be simulated to assess the long term aspects of water quality in the lake.

a) Scenario 1: Design inflow and ambient parameters

The model was run with the design inflow rates and the values of the average day's sampling(May 20 1999) as shown in Table 1.1. The phosphorus content was less than 0.01mg/l for the sampling data. A concentration value of 2 mg/l for Total Phosphorus was given for modelling with 30% Dissolved Phosphorus and 70% Particulate Phosphorus . The modelling results and performance was as shown in Table 1.2. The values of the parameters are the depth averaged concentrations. For the lake, the value was the average of a 3-metre water column depth.

Upper East wetland showed lower performance generally.Since it drained into the Upper North wetland, the overall reduction is reflected in the Upper North's final performance. Except for the Upper East wetlands, the carbon (BOD) removal was 62% - 86%; the nitrogen (ammonia) removal was 86% - 94%; the phosphorus removal was 42% - 67% for dissolved phosphorus and 71% - 83% for particulate phosphorus.

Table 1.1 Parameter inputs for the Model Run.

Parameter		**UN**	**UW**	**UE**	**LE**	**UB**
Design Inflow, m^3/s		0.376	0.188	0.114	0.059	0.137
Temp, ^oC		32.8	37.0	28.2	29.4	30.4
DO, mg/l		6.0	5.2	5.6	5.1	6.0
Ammonia,	mg/l	0.33	0.25	0.28	0.41	0.35
	kg/day	10.72	4.06	2.76	2.09	4.14
Nitrate,	mg/l	1.61	3.67	0.80	0.73	2.64
	kg/day	52.30	59.61	7.88	3.72	31.25

BOD, mg/l	2.0	2.0	2.0	2.0	2.0
kg/day	64.97	32.48	19.70	10.19	23.67
Phosphorus Dis. mg/l	0.6	0.6	0.6	0.6	0.6
Phosphorus Par., mg/l	1.4	1.4	1.4	1.4	1.4
Tot. Phosphorus, mg/l	2.0	2.0	2.0	2.0	2.0
kg/day	64.97	32.48	19.70	10.19	23.67

Table 1.2 Model Performance of the Various Wetlands.

Parameter	**BOD (mg/l)**	**NH (mg/l)**	**NO (mg/l)**	**OP (mg/l)**	**PP (mg/l)**	**DO (mg/l)**
UN*i*	0.300	0.036	0.160	0.158	0.241	3.483
UN*o*	0.042	0.002	0.005	0.055	0.040	1.671
% change	**-86**	**-94**	**-97**	**-65**	**-83**	**-52**
UW*i*	0.307	0.034	0.432	0.170	0.241	2.596
UW*o*	0.042	0.002	0.005	0.055	0.040	1.671
% change	**-86**	**-94**	**-99**	**-67**	**-83**	**-35**
UE*i*	0.091	0.008	0.019	0.080	0.082	2.365
UE*o*	0.050	0.003	0.007	0.060	0.048	1.845
% change	**-45**	**-62**	**-63**	**-25**	**-41**	**-22**
LE*i*	0.163	0.027	0.049	0.088	0.123	1.780
LE*o*	0.038	0.002	0.003	0.051	0.036	1.584
% change	**-76**	**-92**	**-94**	**-42**	**-71**	**-11**
UB*i*	0.082	0.007	0.036	0.058	0.066	1.296
UB*o*	0.031	0.001	0.001	0.028	0.018	0.998
% change	**-62**	**-86**	**-97**	**-52**	**-73**	**-23**
P_Lake	0.031	0.001	0.001	0.029	0.018	1.011

i : inflow at the first cell
o : outflow from the last cell

The particular water quality at the primary lake was within the Lake Water Quality Standards. The DO reflected the immediate oxygen demands and so low values were obtained. This may be contrasted with the mean measured surface DO which were of reasonable concentrations (5.3 - 6.7 mg/l).

The carbon and nitrogen pollutants were decomposed in the wetlands whereas the phosphorus concentration had still not reached equilibrium and was accumulating. The phosphorus is expected to be bound in the sediments or plants. However, the phosphorus contents may be released during high flow when sediments are agitated.

b) Scenario 2: High Hydraulic Loading - High inflow and ambient parameters. Error! Bookmark not defined.

A high hydraulic loading with five times the design inflow and ambient condition for concentration was run to determine the limit of the wetlands performance for high flows. The results were as shown in Table 1.3.

Table 1.3 Model Performance of the Various Wetlands with Five Times Design Inflow.

Parameter	**BOD (mg/l)**	**NH (mg/l)**	**NO (mg/l)**	**OP (mg/l)**	**PP (mg/l)**	**DO (mg/l)**
UN*i*	1.043	0.115	0.535	0.458	0.847	4.221
UN*o*	0.171	0.008	0.018	0.241	0.213	1.817
% change	**-84**	**-93**	**-97**	**-47**	**-75**	**-57**
UW*i*	0.904	0.089	1.143	0.460	0.724	3.266
UW*o*	0.171	0.008	0.018	0.241	0.213	1.817
% change	**-81**	**-91**	**-98**	**-47**	**-70**	**-44**
UE*i*	0.372	0.030	0.079	0.311	0.369	2.795
UE*o*	0.214	0.011	0.030	0.257	0.250	2.048
% change	**-42**	**-63**	**-62**	**-17**	**-32**	**-27**
LE*i*	0.630	0.112	0.199	0.332	0.504	2.666
LE*o*	0.145	0.007	0.012	0.226	0.188	1.682
% change	**-77**	**-94**	**-94**	**-32**	**-62**	**-37**
UB*i*	0.286	0.029	0.170	0.242	0.289	1.661

UB*o*	0.076	0.003	0.003	0.148	0.102	1.069
% change	**-73**	**-89**	**-98**	**-39**	**-65**	**-35**
P_Lake	0.076	0.003	0.003	0.149	0.103	1.077

i : inflow at the first cell
o : outflow from the last cell

With five times the design inflow, the removal rate of carbon(BOD) was 73% to 84% and for nitrogen(ammonia), 89% to 94% by the wetlands except Upper East wetland. There was a better circulation effect as indicated by the higher initial DO value. The water was flowing over faster in the cells.

For Dissolved Phosphorus, the removal rate was 32% to 47% and for Particulate Phosphorus, 62% to 75% which were lower than at design inflow. Phosphorus may be released into the water when agitated at high flow and carried down.

The water quality at the primary lake was within Ambient Lake Standards for BOD and nitrogen. For total phosphorus(= 0.252 mg/l), it was higher than ambient Standards(=0.05 mg/l).

At high discharges therefore, the wetlands are unabled to remove the phosphorus sufficiently due to the shorter retention times.

c) **Scenario 3**: Sewage Loading and half design inflow.

A loading of treated sewage discharge to all the wetlands with half the design inflow as in Table 1.4 was run to simulate the performance at high concentration loading. The results are in Table 1.5.

Table 1.4 Sewage Loading Parameters

Parameter input	**Concentration**	**Loading, kg/day**				
		UN	**UW**	**UE**	**LE**	**UB**
Inflow, m^3/s	-	0.188	0.094	0.057	0.029	0.068
Temp, ^oC	30.0	-	-	-	-	-
DO, mg/l	5.0	-	-	-	-	-
Ammonia, mg/l	10.0	162.5	81.1	49.2	24.9	58.8
Nitrate, mg/l	10.0	162.5	81.1	49.2	24.9	58.8
BOD, mg/l	20	324.9	162.2	98.4	49.9	117.6

Phosphorus Dis., mg/l	0.6	9.8	4.8	2.9	1.4	3.4
Phosphorus Par., mg/l	1.4	22.8	11.3	6.9	3.6	8.2

Table 1.5 Model Performance of the Various Wetlands with Sewage Loading

Parameter	**BOD (mg/l)**	**NH (mg/l)**	**NO (mg/l)**	**OP (mg/l)**	**PP (mg/l)**	**DO (mg/l)**
UN*i*	1.647	0.568	0.690	0.089	0.131	1.926
UN*o*	0.183	0.020	0.027	0.028	0.021	1.322
% change	**-89**	**-96**	**-96**	**-68**	**-84**	**-31**
UW*i*	1.846	0.787	0.839	0.101	0.142	1.532
UW*o*	0.183	0.020	0.027	0.028	0.020	1.322
% change	**-90**	**-97**	**-81**	**-72**	**-86**	**-14**
UE*i*	0.457	0.114	0.139	0.043	0.043	1.698
UE*o*	0.227	0.031	0.044	0.031	0.024	0.889
% change	**-50**	**-73**	**-68**	**-28**	**-44**	**-47**
LE*i*	0.806	0.339	0.346	0.046	0.063	1.302
LE*o*	0.157	0.015	0.019	0.026	0.018	1.283
% change	**-80**	**-95**	**-94**	**-43**	**-71**	**-1**
UB*i*	0.382	0.091	0.081	0.030	0.034	0.881
UB*o*	0.084	0.005	0.004	0.013	0.009	0.876
% change	**-78**	**-94**	**-95**	**-56**	**-73**	**-1**
P_Lake	0.083	0.005	0.004	0.013	0.009	0.889

i : inflow at the first cell
o : outflow from the last cell

With low flow, there are longer retention time for wetland processes. The removal rate was generally better. For carbon(BOD), 78%-90%; for nitrogen(ammonia), 94%-97%; for dissolved phosphorus, 43%-72% and for particulate phosphorus, 71%-86% except Upper East which flows into Upper North wetland. With high pollutant loading and less flushing, the water became septic as indicated by the low DO in the inflows and outflows of the wetlands.

The water quality at the primary lake was within Ambient Lake Water Standards.

2.0 Model summary and discussion

From the simulation of the dynamic processes of the water quality, it was predicted that the wetlands performed well for the removal of BOD and nitrogen even with typical treated sewage effluents. For phosphorus, the uptake by plants in the wetlands should remove the accumulated phosphorus in the sediments. The plants debris and dying plants must be regularly removed to improve the uptake of phosphorus and reduce the accumulated sink in the wetlands.

The model results was comparable to the designed wetlands performance as reported in Putrajaya Lake Phase 1: Concept Design Report - Wetland Component (Perbadanan Putrajaya,1996). The report indicated that the removal of the main nutrients by the wetlands processes should be:

1. 20-80% for Phosphorus,
2. 90% for Nitrogen and
3. 50-90% for carbon

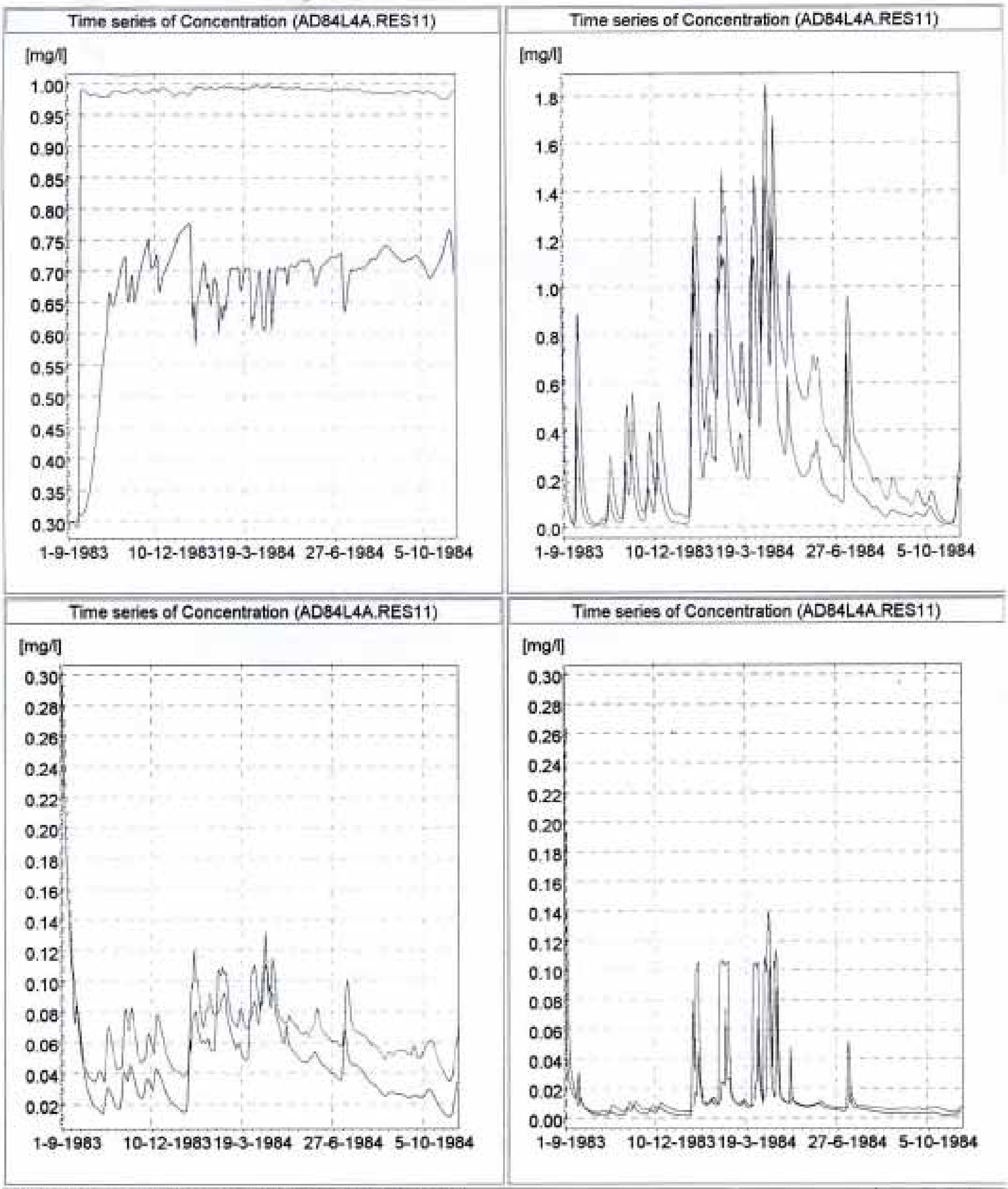
based on the earlier Water Quality Control and Management Study report (Kumpulan Perunding Kota Bistari, 1997).

For high flow scenario, phosphorus levels were higher. It was supposed that this was due to particulate BOD and phosphorus being be carried in suspension by the faster stream flow and short-circuiting of processes in each cell will occur. To prevent such occurrence, the placement of vegetation and the planting density must be able to reduce flow and trap a reasonable amount of these particulates at regular high run-off. In addition, there should be land management measures to reduce high runoff flow velocities. However, as high flow is only intermittent and pollutant dilution will occur, high flow condition is not regarded to be a major problem.

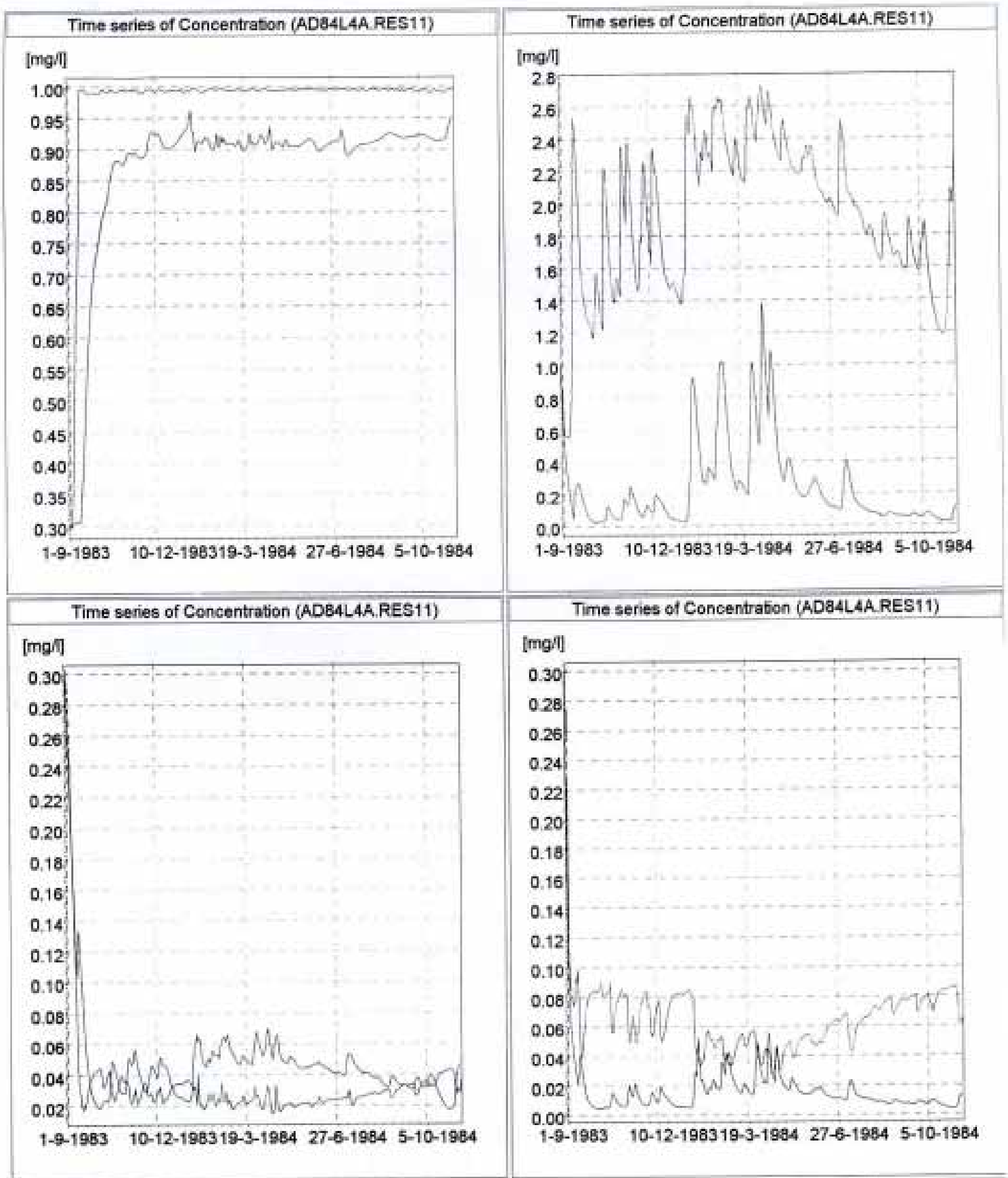
At low flow, as in the dry season, the model predicted that the water quality better water quality conditions in general. The Dissolved Oxygen levels were reduced, however, probably due to the low flow conditions and degradation of organic waste inside the cells. At such conditions, the water quality may deteriorate if there were sewage inflow into the wetland cells. The higher organic load would require more oxygen for degradation. The water may then become septic and regular pump-back or recirculation from the lake will be needed at dry season to increase flow and aerate the water plants.

APPENDIX 2.5

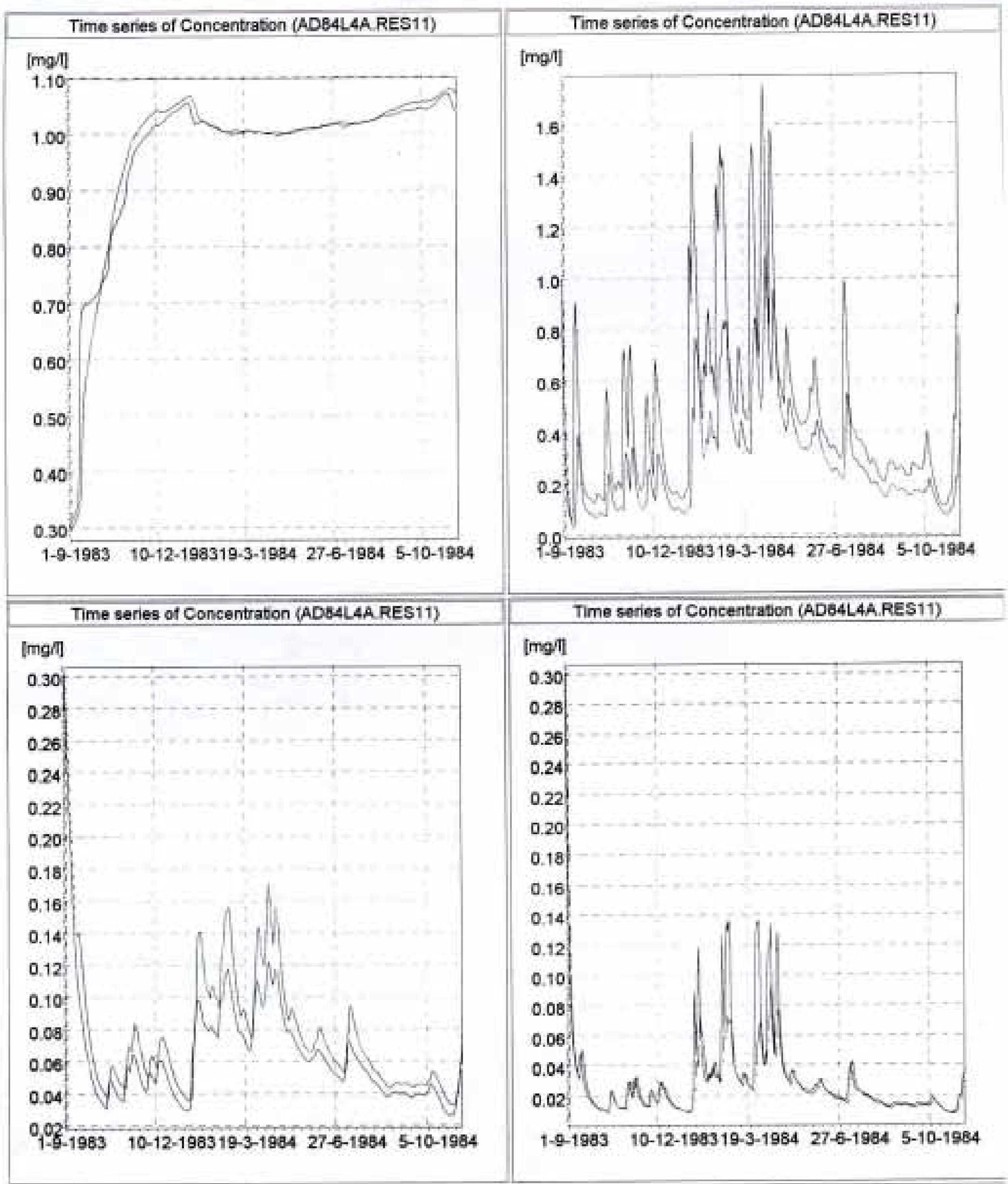
TIME SERIES OF CONCENTRATION FOR THE 1984-RUN



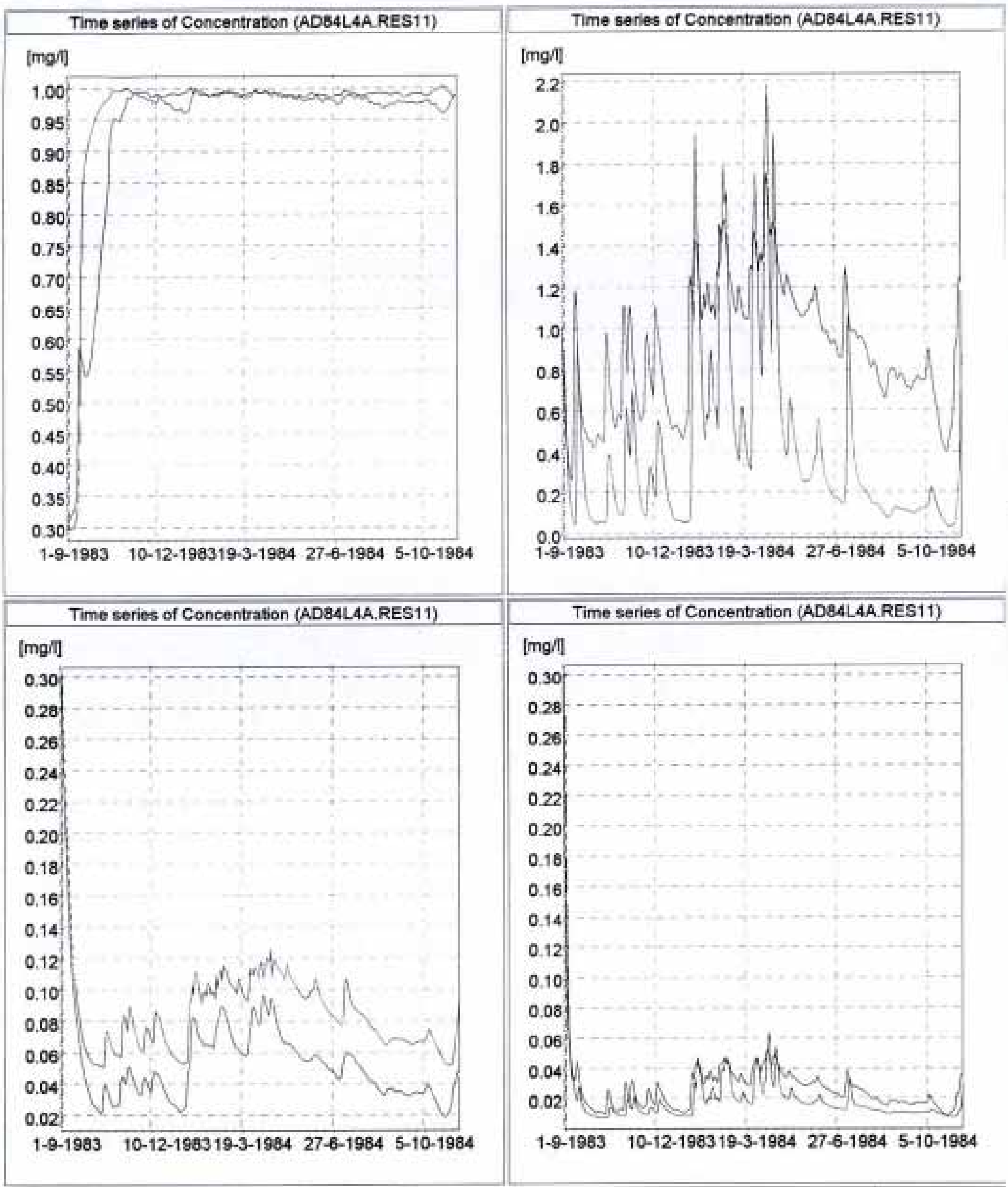
Time Series of Concentrations (1984 run)
for Upper-West wetland Top and Last Cell
NH_3, BOD
Dis.P, Par.P



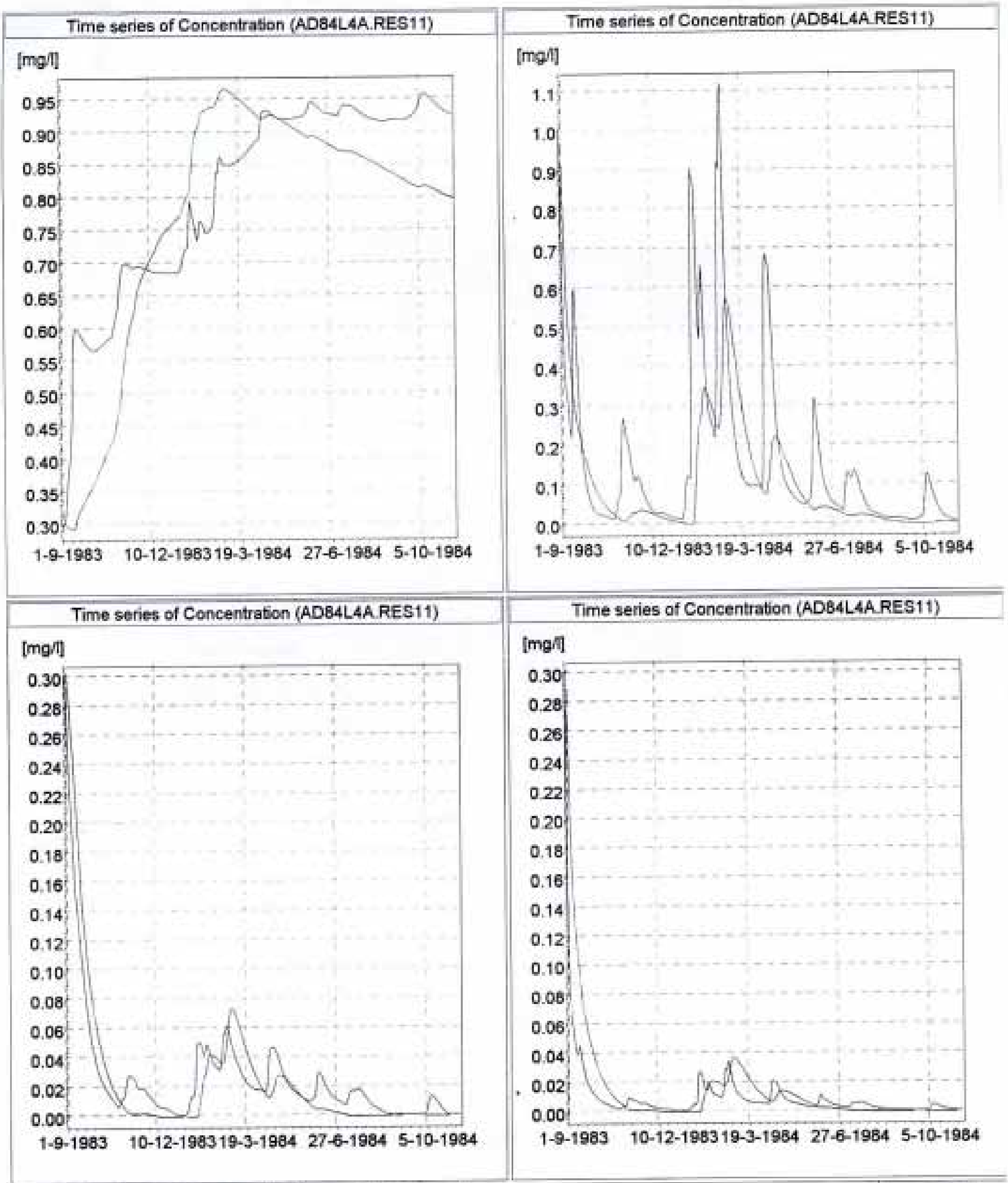
Time Series of Concentrations (1984 run)
for Upper-North wetland Top and Last Cell
NH3, BOD
Dis.P, Par.P



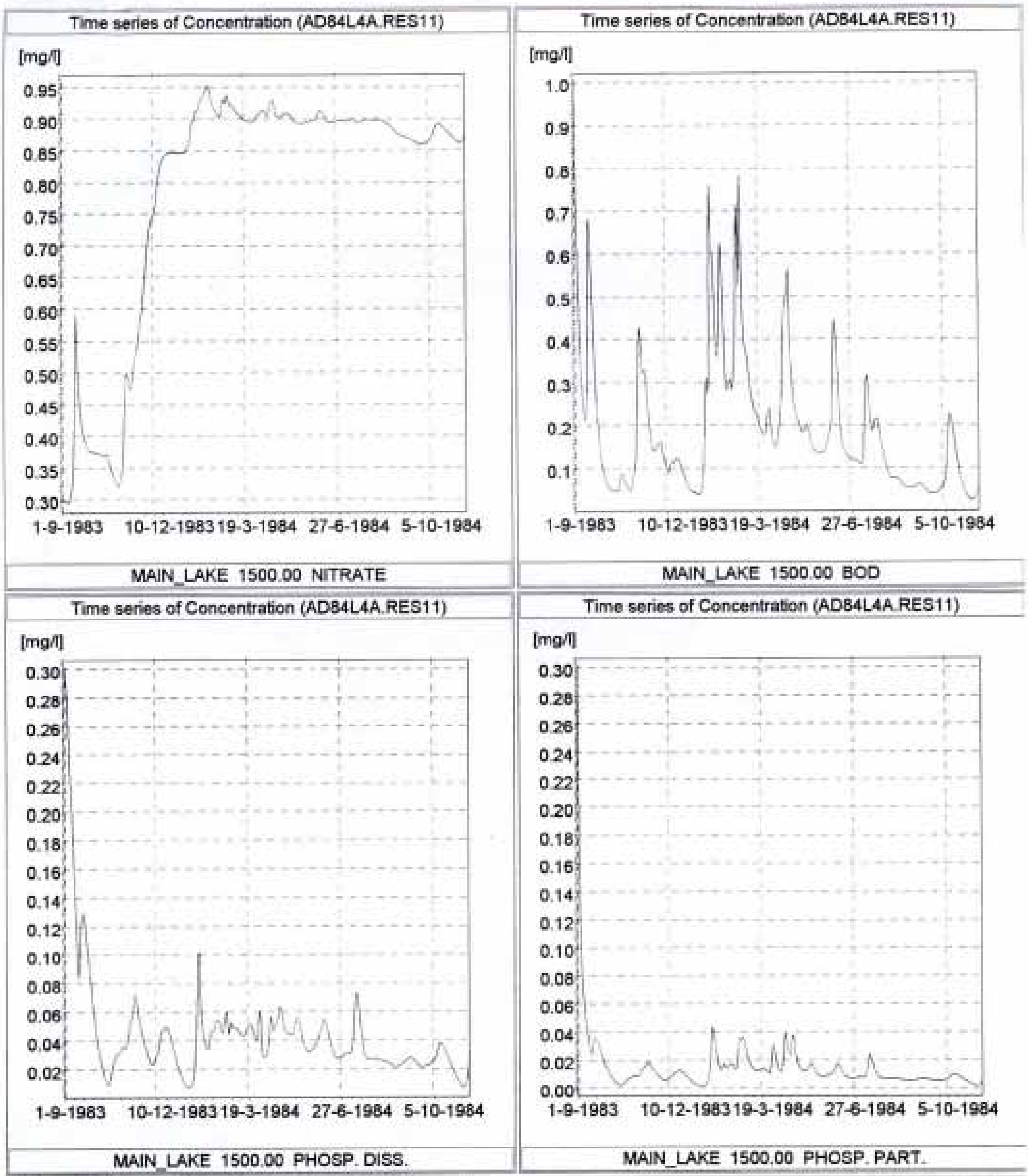
Time Series of Concentrations (1984 run)
for Upper-East wetland Top and Last Cell
NH3, BOD
Dis.P, Par.P



Time Series of Concentrations (1984 run)
for Lower-East wetland Top and Last Cell
NH3, BOD
Dis.P, Par.P



Time Series of Concentrations (1984 run)
for Upper-Bisa wetland Top and Last Cell
NH_3, BOD
Dis.P, Par.P

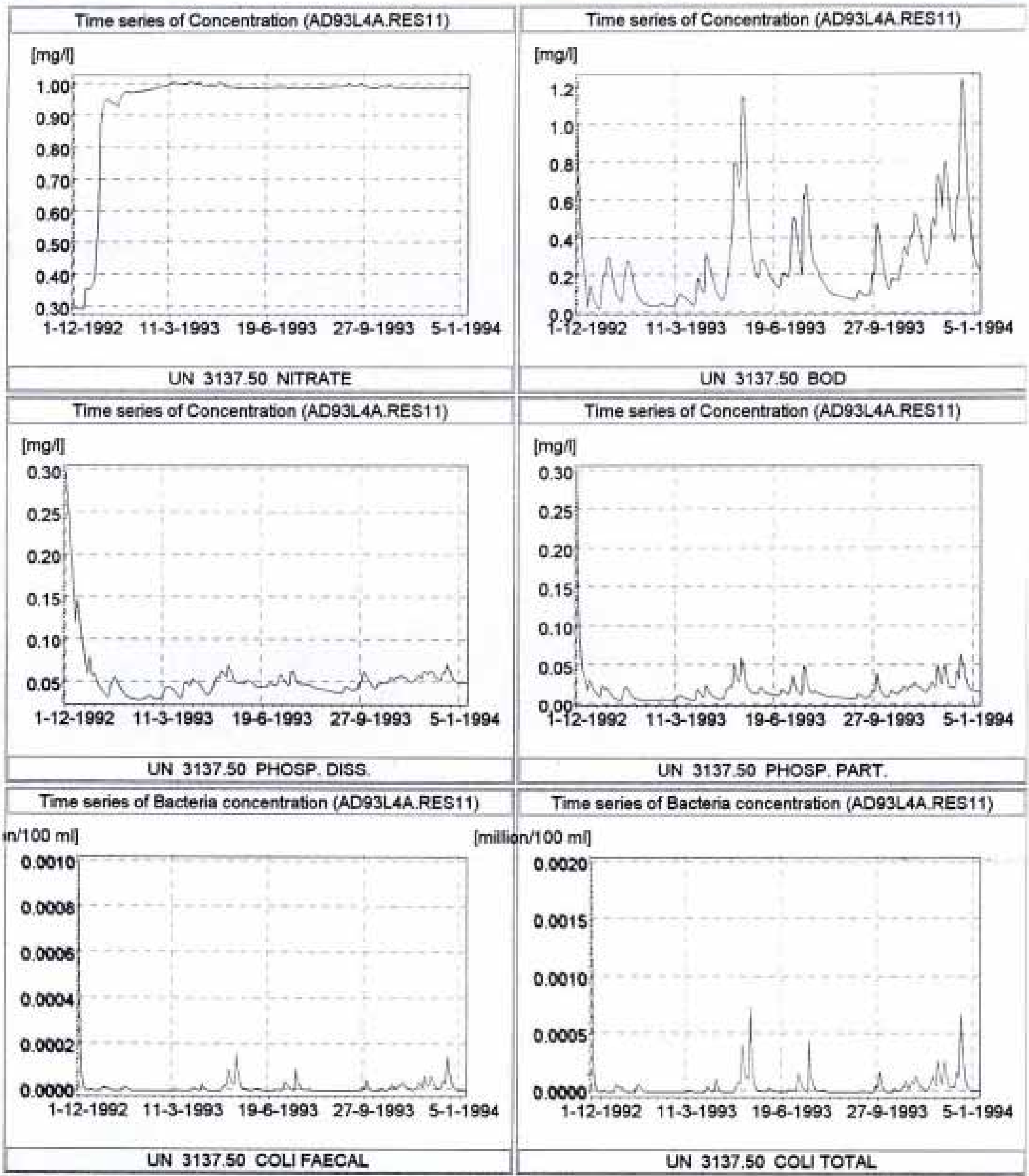


Time Series of Concentrations (1984 run)
for Primary Lake
NH3, BOD
Dis.P, Par.P

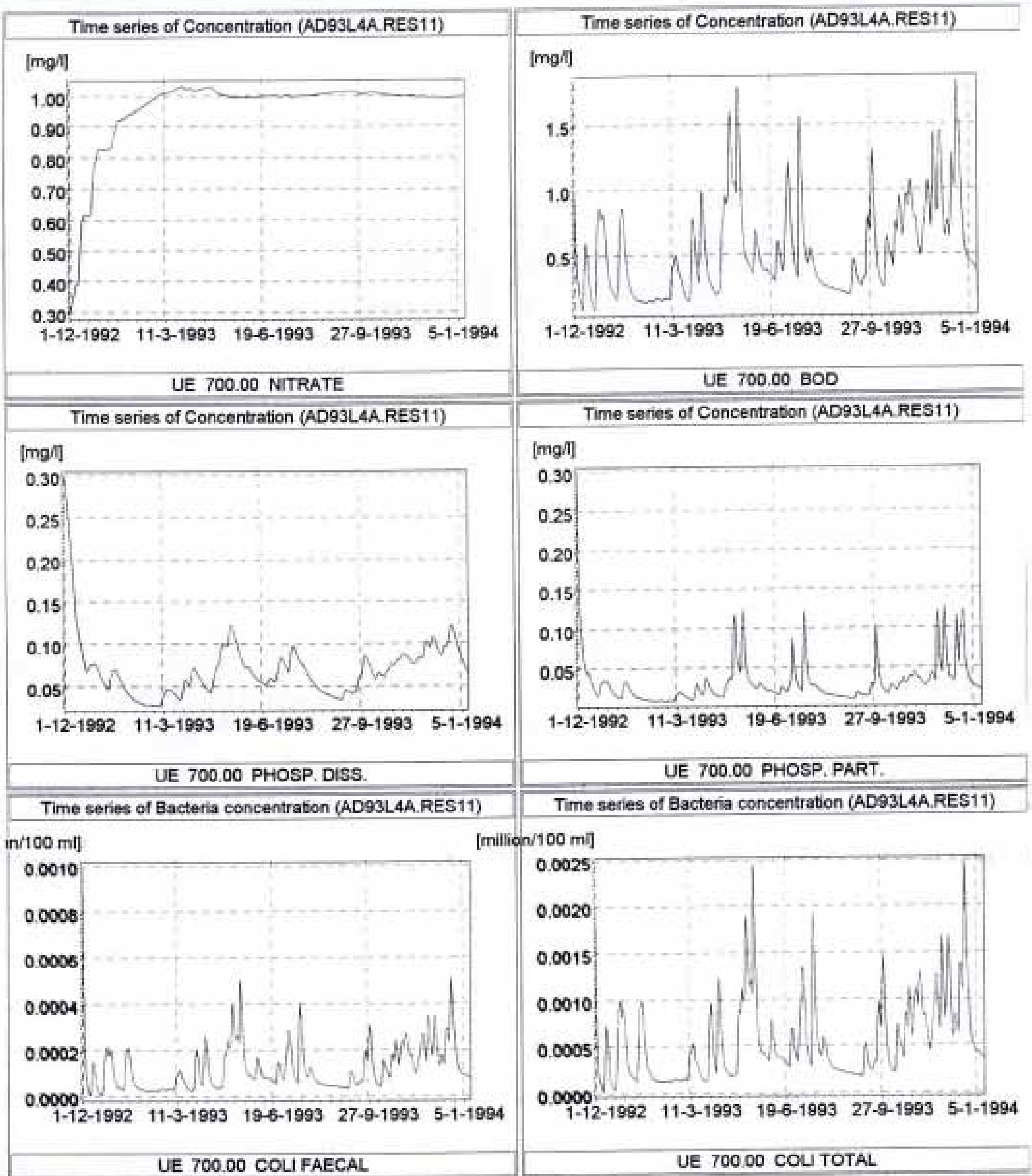
Figure 2.6.7

APPENDIX 2.6

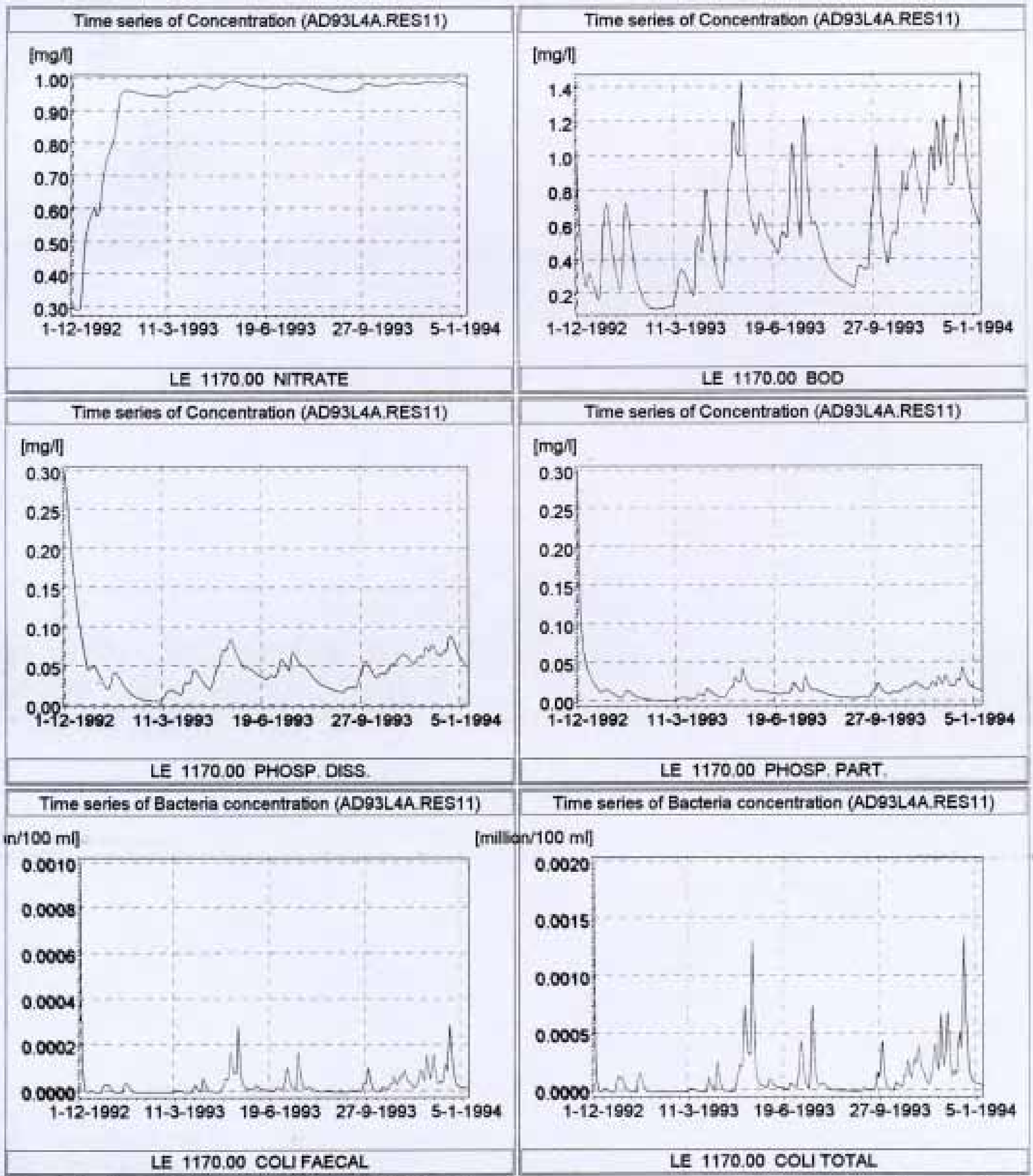
TIME SERIES OF CONCENTRATION FOR THE 1993-RUN



Time Series of Concentrations (1993 run)
for Upper-North wetland Last Cell
NH3, BOD
Dis.P, Par.P
Fcoli, Tcoli

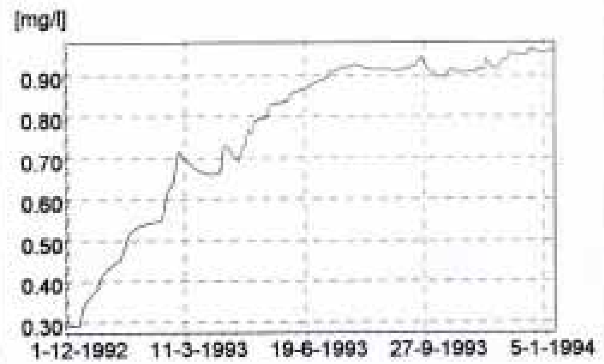


Time Series of Concentrations (1993 run)
for Upper-East wetland Last Cell
NH3, BOD
Dis.P, Par.P
Fcoli, Tcoli



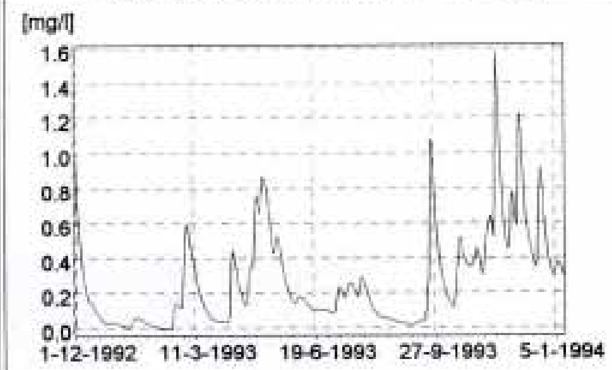
Time Series of Concentrations (1993 run)
for Lower-East wetland Last Cell
NH3, BOD
Dis.P, Par.P
Fcoli, Tcoli

Time series of Concentration (AD93L4A.RES11)



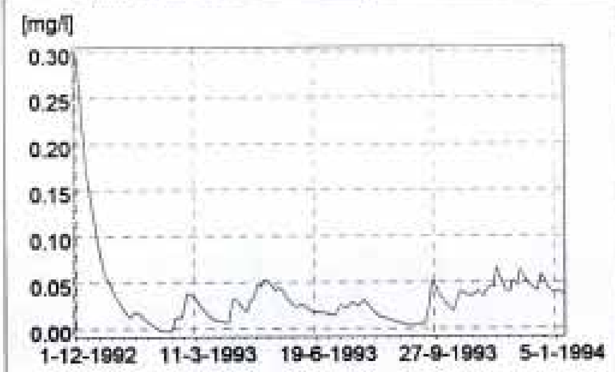
UB 1523.00 NITRATE

Time series of Concentration (AD93L4A.RES11)



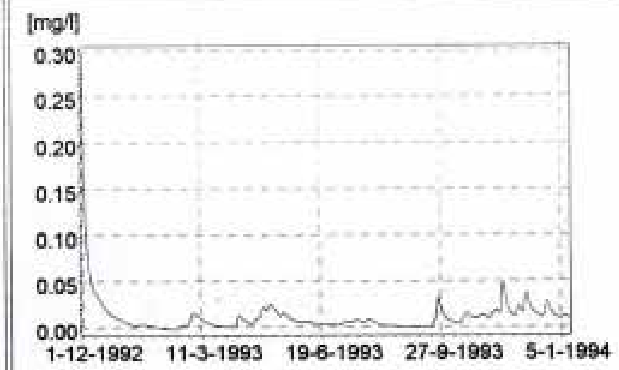
UB 1523.00 BOD

Time series of Concentration (AD93L4A.RES11)



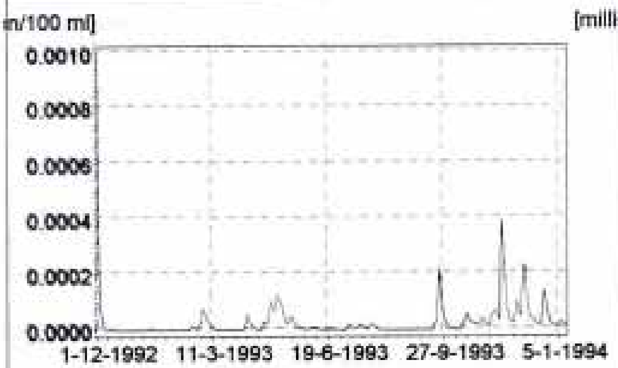
UB 1523.00 PHOSP. DISS.

Time series of Concentration (AD93L4A.RES11)



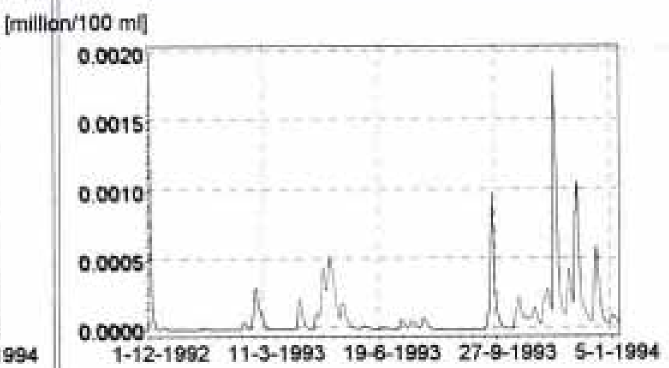
UB 1523.00 PHOSP. PART.

Time series of Bacteria concentration (AD93L4A.RES11)



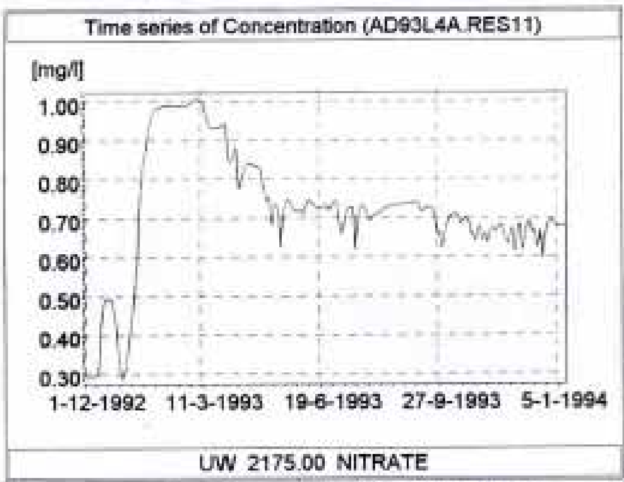
UB 1523.00 COLI FAECAL

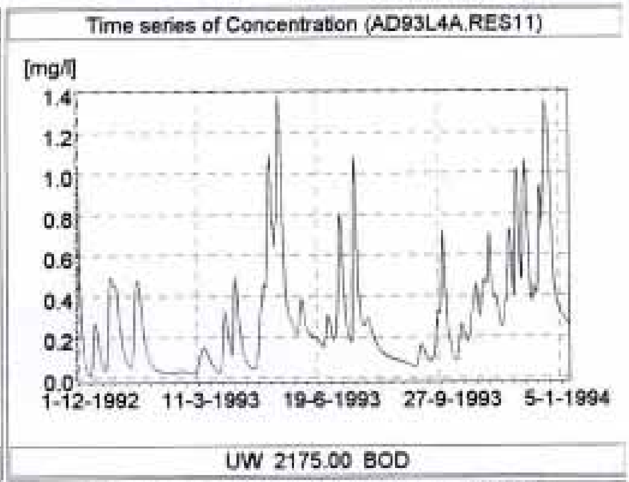
Time series of Bacteria concentration (AD93L4A.RES11)

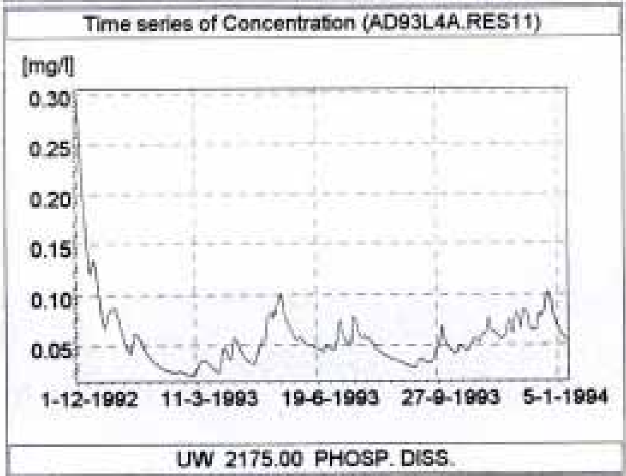


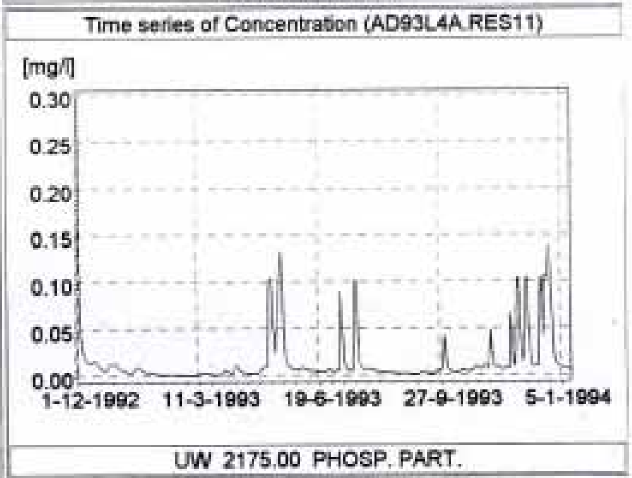
UB 1523.00 COLI TOTAL

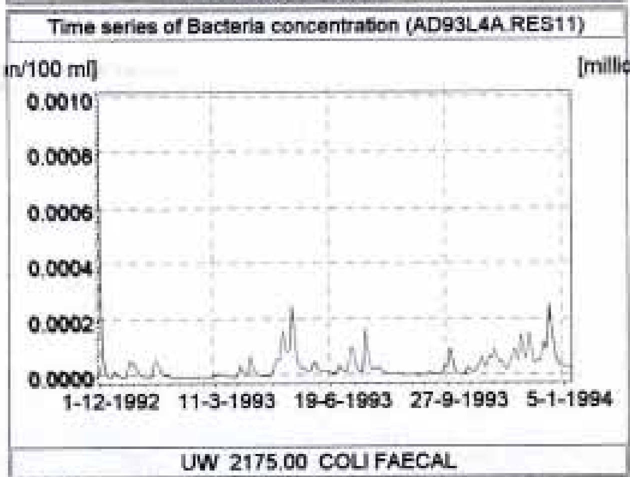
Time Series of Concentrations (1993 run)
for Upper-Bisa wetland Last Cell
NH3, BOD
Dis.P, Par.P
Fcoli, Tcoli

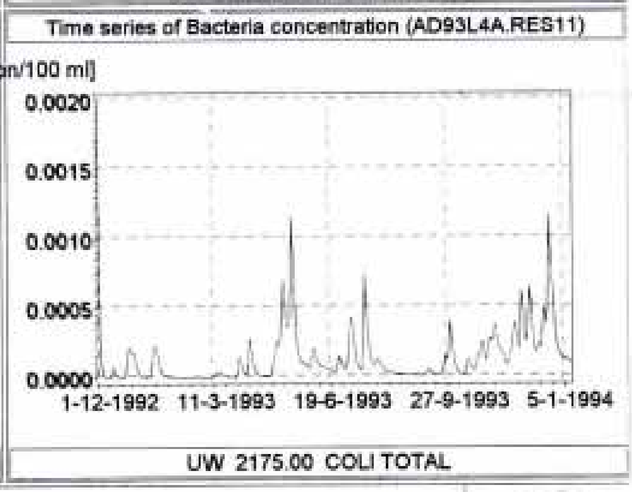




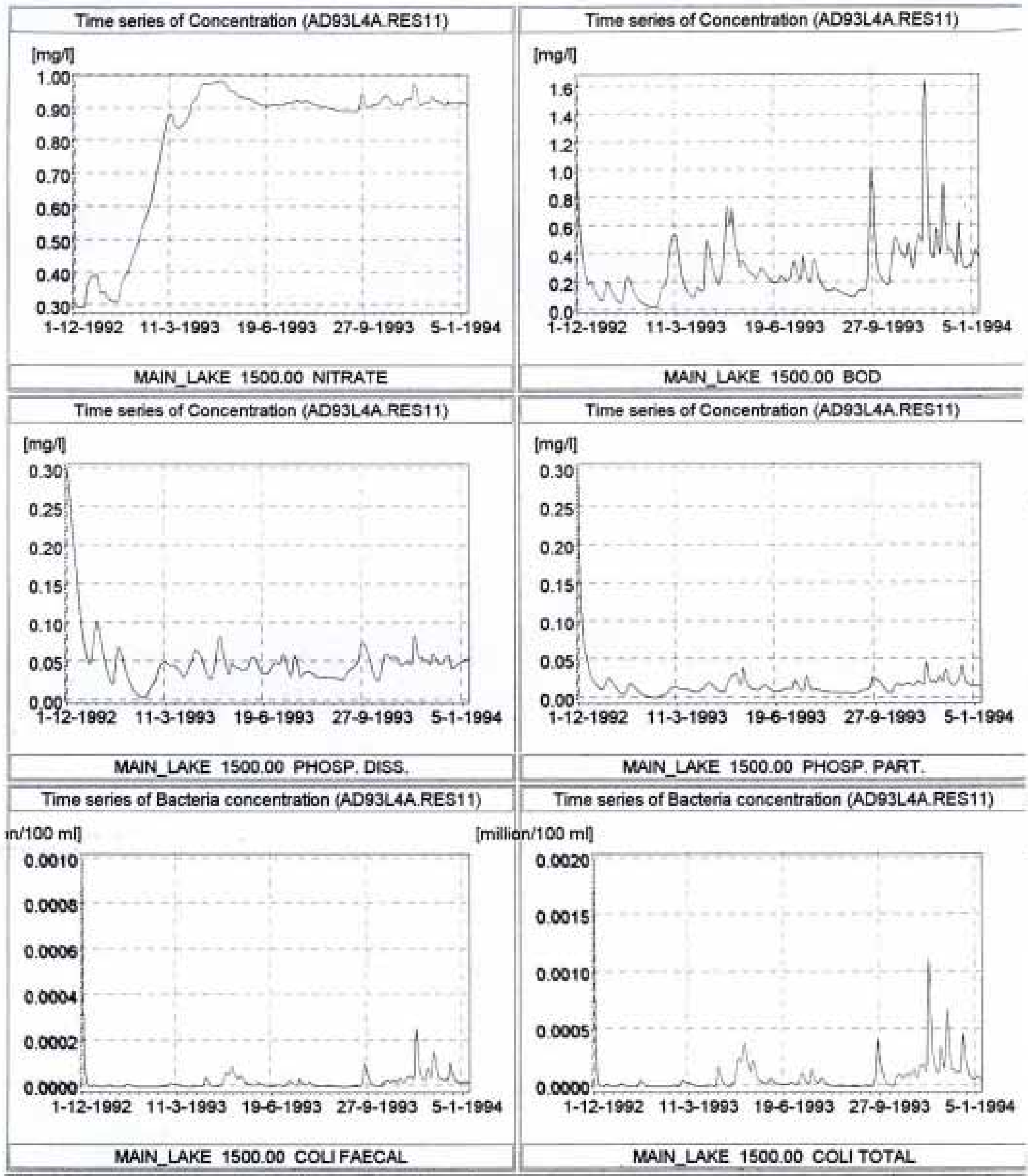








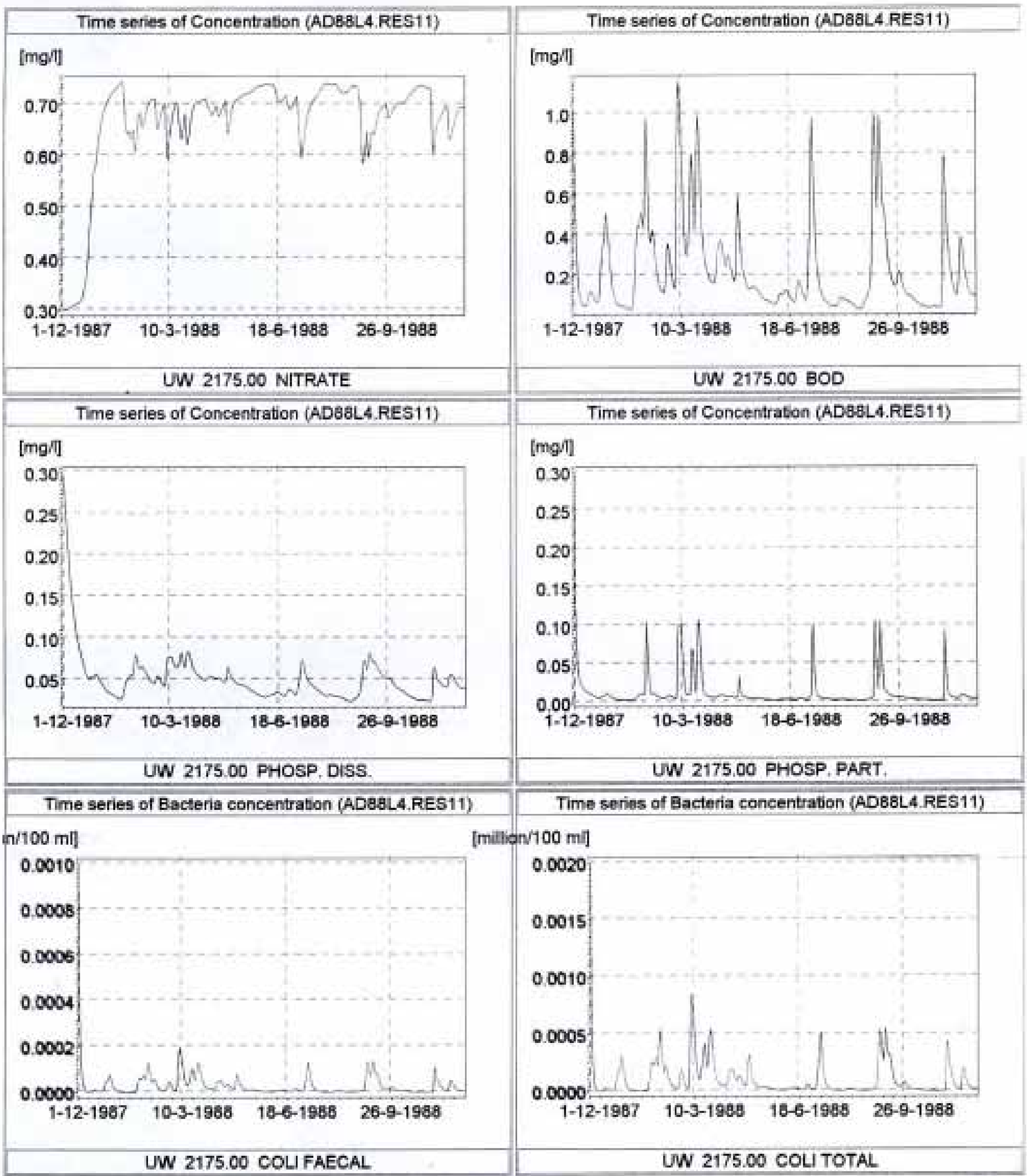
Time Series of Concentrations (1993 run)
for Upper-West wetland Last Cell
NH3, BOD
Dis.P, Par.P
Fcoli, Tcoli



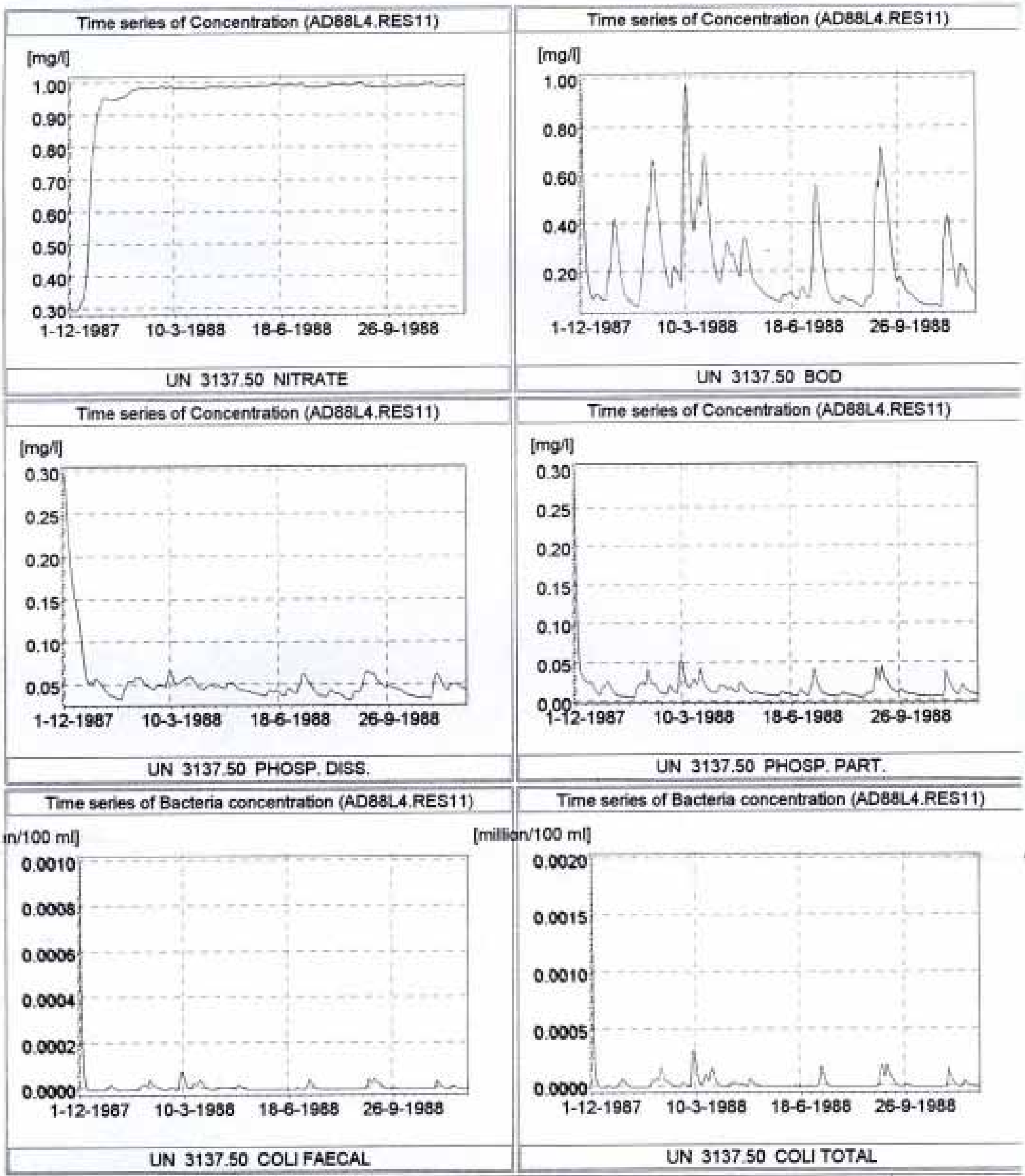
Time Series of Concentrations (1993 run)
for Primary Lake
NH3, BOD
Dis.P, Par.P
Fcoli, Tcoli

APPENDIX 2.7

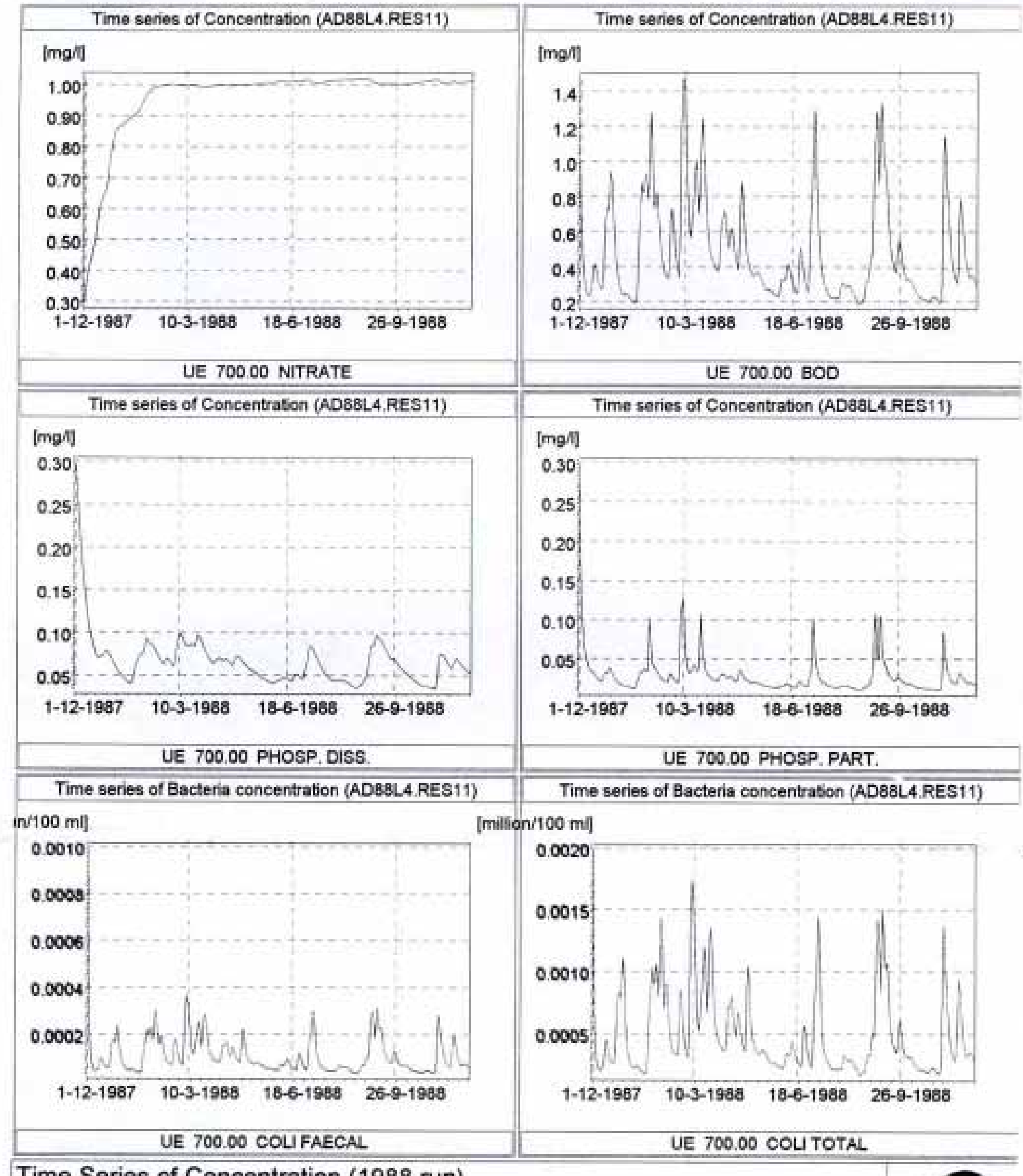
TIME SERIES OF CONCENTRATION FOR THE 1988-RUN



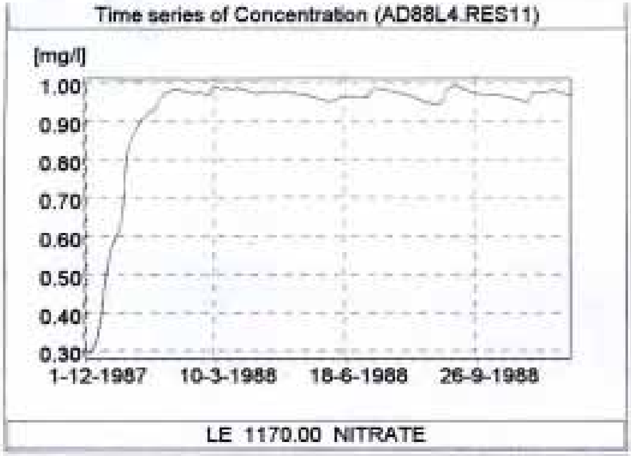
Time Series of Concentration (1988 run)
for Upper-West wetland Last Cell
NH3, BOD
Dis.P, Par.P
Fcoli, Tcoli

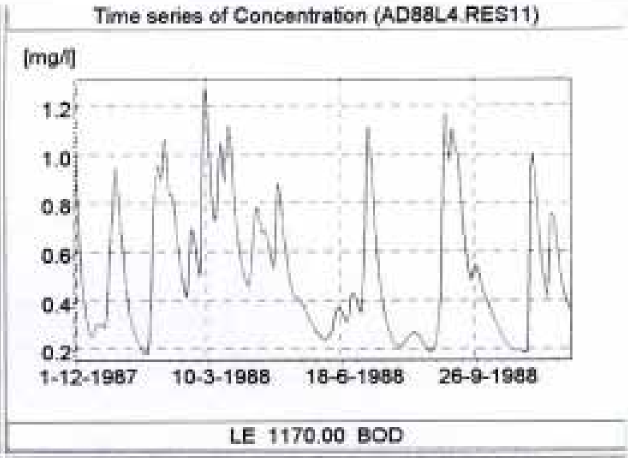


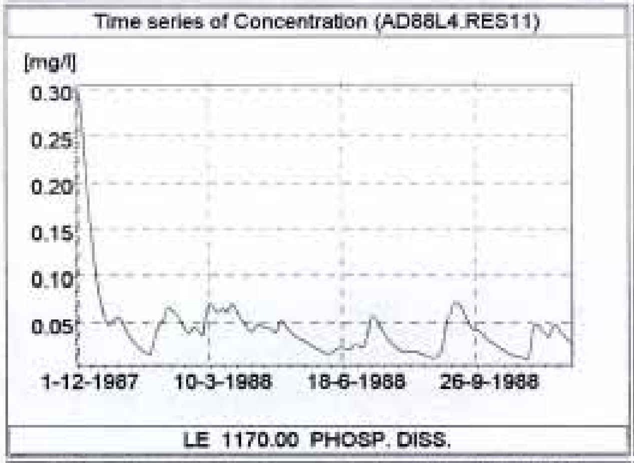
Time Series of Concentration (1988 run)
for Upper-North wetland Last Cell
NH_3, BOD
Dis.P, Par.P
Fcoli, Tcoli

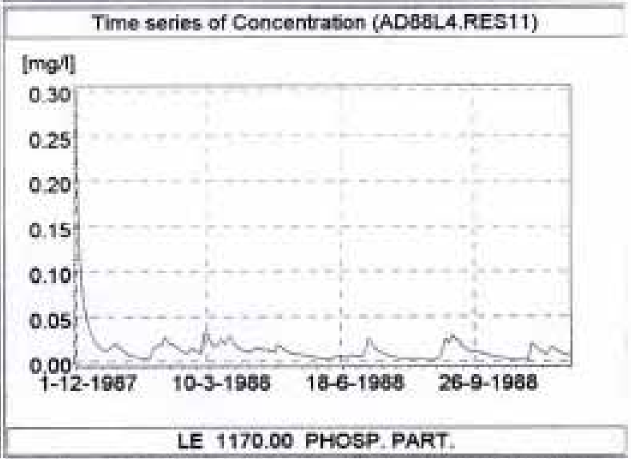


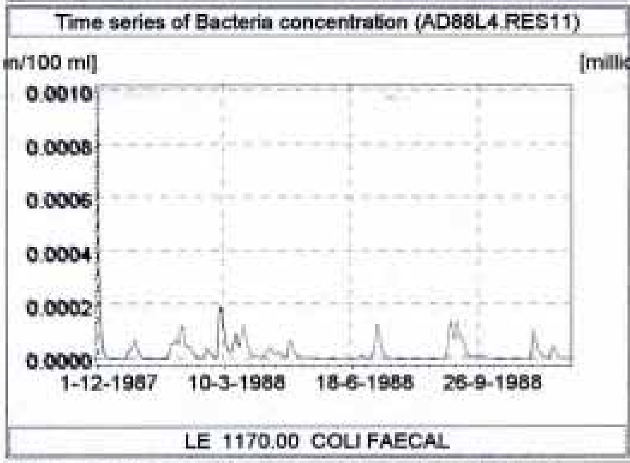
Time Series of Concentration (1988 run)
for Upper-East wetland Last Cell
NH3, BOD
Dis.P, Par.P
Fcoli, Tcoli

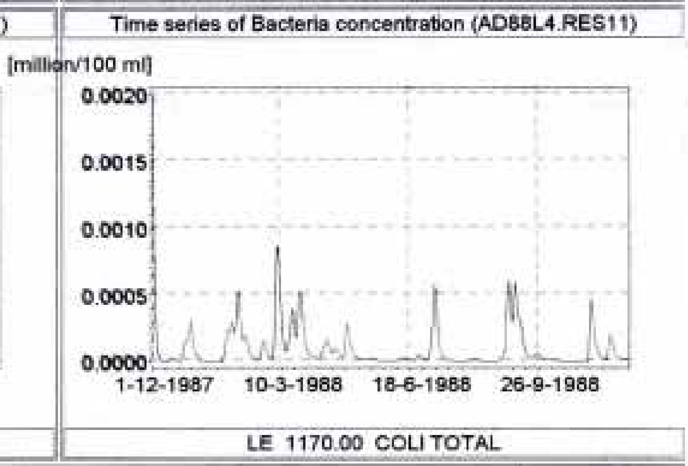






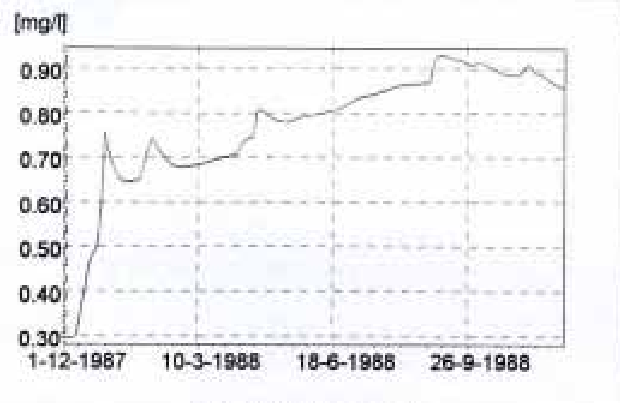






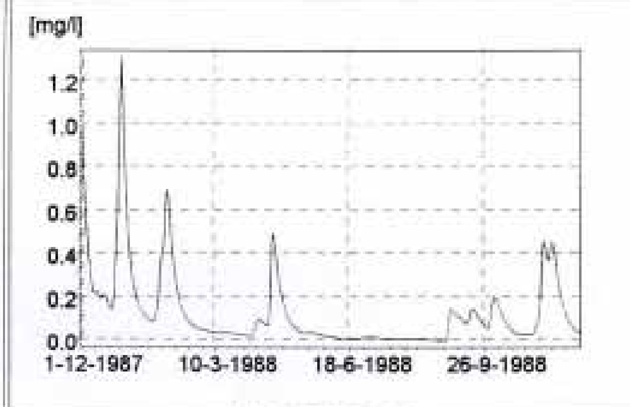
Time Series of Concentration (1988 run)
for Lower-East wetland Last Cell
NH3, BOD
Dis.P, Par.P
Fcoli, Tcoli

Time series of Concentration (AD88L4.RES11)



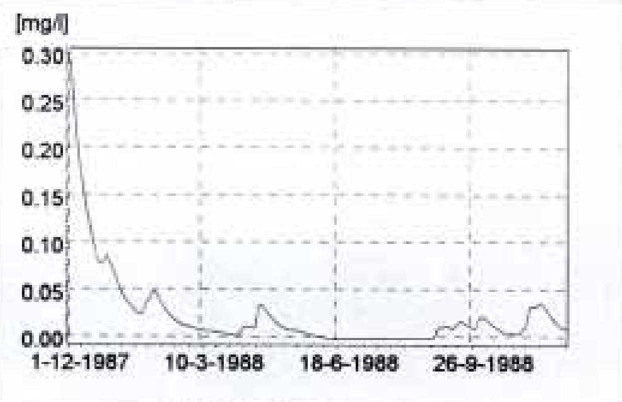
UB 1523.00 NITRATE

Time series of Concentration (AD88L4.RES11)



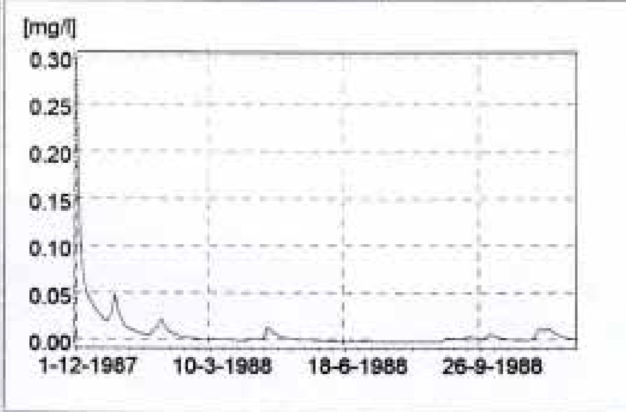
UB 1523.00 BOD

Time series of Concentration (AD88L4.RES11)



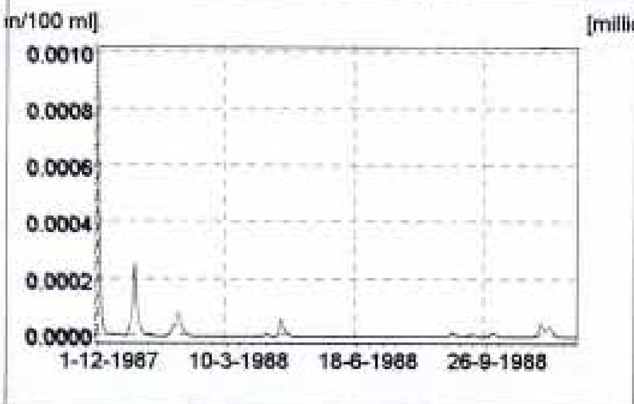
UB 1523.00 PHOSP. DISS.

Time series of Concentration (AD88L4.RES11)



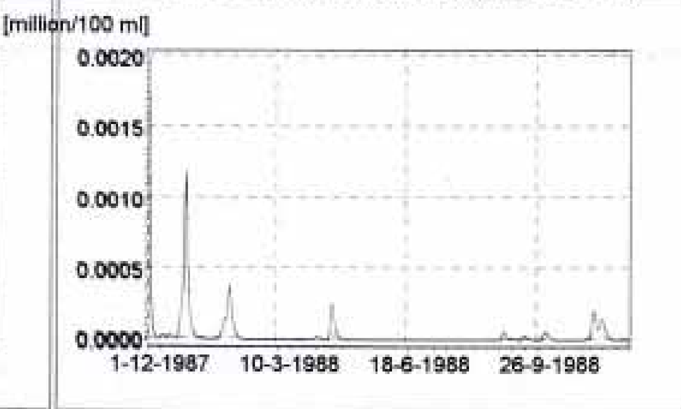
UB 1523.00 PHOSP. PART.

Time series of Bacteria concentration (AD88L4.RES11)



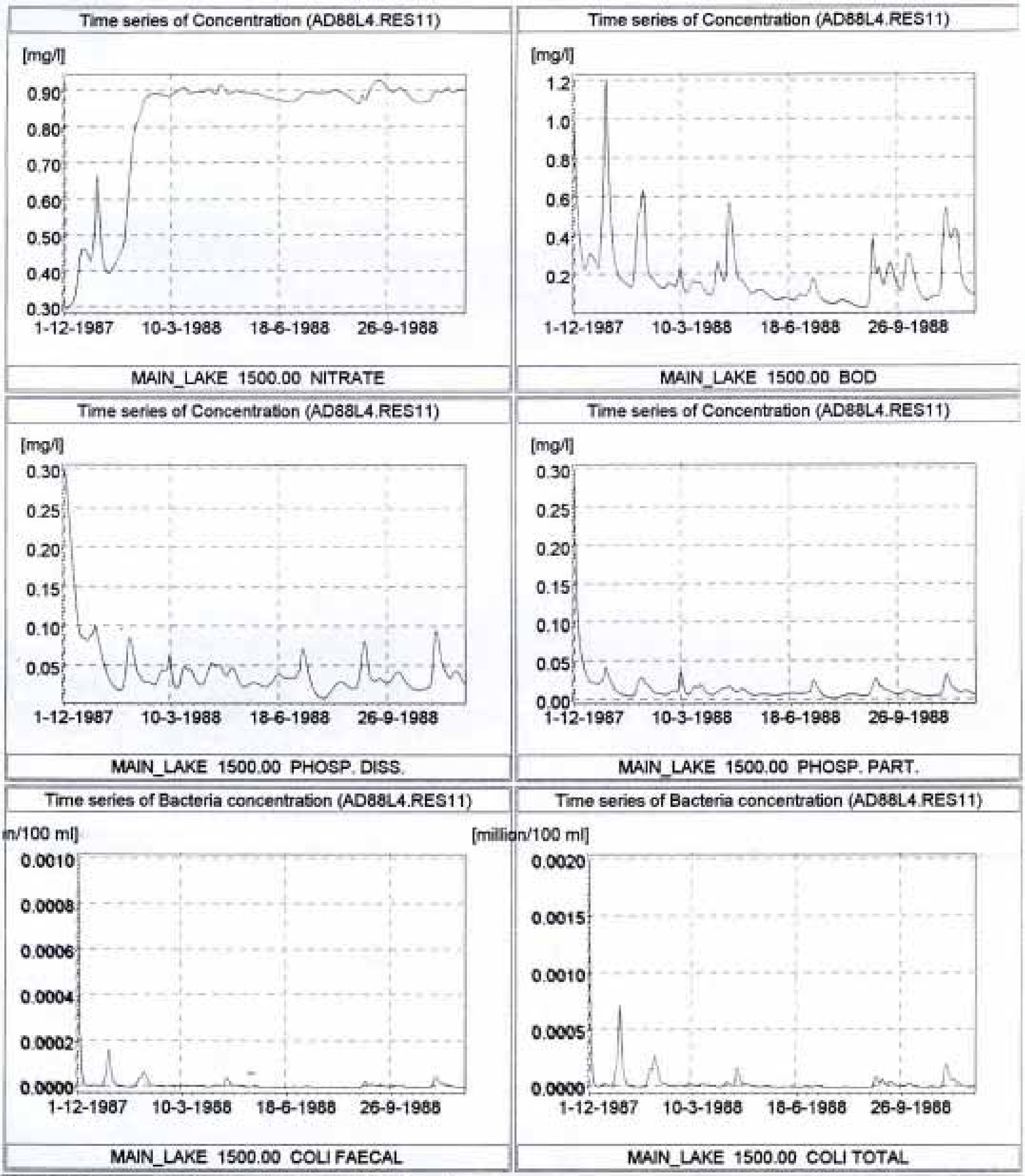
UB 1523.00 COLI FAECAL

Time series of Bacteria concentration (AD88L4.RES11)



UB 1523.00 COLI TOTAL

Time Series of Concentration (1988 run)
for Upper-Bisa wetland Last Cell
NH3, BOD
Dis.P, Par.P
Fcoli, Tcoli



Time Series of Concentration (1988 run)
for Primary Lake
NH3, BOD
Dis.P, Par.P
Fcoli, Tcoli

Figure 2.6.7

APPENDIX A

PUTRAJAYA LAKE CATCHMENT

FERTILIZER USE GUIDELINES

APPENDIX A

PUTRAJAYA LAKE CATCHMENT FERTILIZER USE GUIDELINES

1.0 FERTILIZERS

1.1 GENERAL INFORMATION

1.1.1 Fertilizers are substances that are added to the soil to increase its fertility for plant growth. There are 18 elements essential to plant growth. They may be divided into macronutrients and micronutrients (Table 1). If plants lack any of these nutrients, they will exhibit signs of nutrient deficiency.

Table 1 Plant nutrient requirements

Macronutrients		Micronutrients
Primary	**Secondary**	
Carbon (C) Hydrogen (H) Oxygen (O) Nitrogen (N) Phosphorous (P) Potassium (K)	Calcium (Ca) Magnesium (Mg) Sulfur (S) Chlorine (Cl) Sodium (Na)	Iron (Fe) Zinc (Zn) Manganese Mn) Copper (Cu) Molybdenum (Mo) Boron (B) Cobalt Co)

1.1.2 Most plants receive a natural supply of nitrogen, phosphorus and potassium from organic matter and soil minerals, but this is not usually sufficient to satisfy the demands of crop plants, including ornamental plants.

1.1.3 The primary nutrients are most likely to be present in inadequate amounts and therefore are frequently added through use of fertilizers.

1.1.4 The amount of a nutrient element present in a fertilizer formulation is based on percentage of weight and is normally given as a ratio of three numbers: The percentage by weight of nitrogen (N), phosphate (P2O5), and potash (K2O) respectively. These numbers are said to represent nitrogen, phosphorus, and potassium, or N-P-K. Sometimes there is a fourth number, which represents the amount of sulfur (S) in the mix. The rest of the fertilizer's weight is filler which allows even spreading of the fertilizer.

1.1.5 The best fertilizer to use depends on many factors, such as the nutrients needed, soil structure, soil chemistry, and method of applying the fertilizer.

1.2 TYPES OF FERTILIZERS

1.2.1 Complete vs Incomplete

1.2.1.1 A fertilizer is said to be complete when it contains nitrogen, phosphorus, and potassium. Examples of commonly used fertilizers are 10-10-10, 16-16-16, and 20-10-5.

1.2.1.2 An incomplete fertilizer will be missing at least one of the major components. Incomplete fertilizers can be blended together to make complete fertilizers.

1.2.1.3 The specific fertilizer ratio needed depends on the soil nutrient level. For example, a 1-1-1 ratio (10-10-10, 15-15-15, 20-20-20, etc.) is widely used at the time of lawn establishment, but established lawns generally respond better to fertilizer ratios high in nitrogen. Two of the more common complete fertilizers used by homeowners for flowers and vegetables are 10-10-10 and 5-10-10.

1.2.2 Slow-Release Fertilizers

1.2.2.1 Plants can absorb nutrients continuously, so it is beneficial to provide them with a balance of nutrients throughout their growth. An efficient way to achieve this is to apply a slow-release fertilizer, which releases nutrients at a rate that makes them available to the plants over a long period. Slow-release fertilizers contain one or more nutrients. Slow-release fertilizers can be categorized according to their release mechanism. The three major types of nutrient release mechanisms are:

1) materials that dissolve slowly,
2) materials which must be decomposed by soil microorganisms in order to release nitrogen, and
3) granular materials with coatings made of resin or sulfur to control the rate of nutrient release into the soil.

1.2.2.2 Sulphur-coated urea is a slow-release nitrogen fertilizer with a covering of sulfur around each urea particle. Different thicknesses of sulfur control the rate of nitrogen release, which increases with temperature. Watering does not affect its release rate. Sulfur-coated urea applied to the soil's surface releases nitrogen more slowly than if incorporated into the soil. This material generally costs less than other slow-release fertilizers, and it also supplies the second nutrient, sulfur.

1.2.2.3 When fertilizer products coated with multiple layers of resin come into contact with water, the layers swell and increase the pore size in the resin so that the dissolved fertilizer can move into the soil. Release rate depends on the coating thickness, temperature, and water content of the soil. There is often a large release of fertilizer during the first two or three days after application. Release timing can be from 0 to 6 months, depending on the coating.

1.2.2.4 Slow-release fertilizers need not be applied as frequently as other fertilizers, and higher amounts can be applied without danger of burning. Plants may use the nitrogen in slow-release fertilizers more efficiently than nitrogen in other forms, since it is released over a longer period of time and in smaller quantities. Slow-release fertilizers are generally more expensive than other types. The real benefit, however, is the frequency of application, which is much lower than conventional fertilizers.

1.2.2.5 Urea formaldehyde and sulfur-coated urea have been used as turf fertilizer, while resin-coated fertilizers are predominantly used in container growing.

Table 2 Comparison of Fertilizers

Advantages	Disadvantages
Conventional Fertilizers	
1. Fast acting. 2. Some are acid-forming. 3. Low cost.	1. Greater burn potential. 2. Solidifies in the bag when wet. 3. Nitrogen leaches readily.
Slow-Release Fertilizers	
1. Fewer applications. 2. Low burn potential. 3. Release rate varies depending on fertilizer characteristics. 4.Comparatively slow release rate.	1. Unit cost is high. 2. Availability is limited. 3. Release rate governed by factors other than plant need
Manures or Sewage Sludge	
1. Low burn potential. 2. Relatively slow release. 3. Contain micronutrients. 4. Conditions the soil.	1. Salt could be a problem. 2. Bulky, difficult to handle. 3. Odou.r 4. Expensive per pound of actual nutrient. 5. Weed seeds can be a problem. 6. Heavy metals may be present in sewage sludge.

1.2.3 Organic Fertilizers

1.2.3.1 The word organic, applied to fertilizers, simply means that the nutrients contained in the product are derived solely from the remains or by-products of a once-living organism. Urea is a synthetic organic fertilizer, an organic substance manufactured from inorganic materials (although urea is also, as the name implies, a constituent of urine). Cottonseed meal, blood meal, bone meal, hoof and horn meal, and all manures are examples of organic fertilizers. When packaged as fertilizers, these products will have the fertilizer ratios stated on the labels.

1.2.3.2 Some organic materials, particularly composted manures and sludges, are sold as soil conditioners and do not have a nutrient guarantee, although small amounts of nutrients are present. Most are high in one of the three major nutrients and low in the other two, although you may find some fortified with nitrogen, phosphorus, or potash for a higher analysis. Many are low in all three.

1.2.3.3 In general, organic fertilizers release nutrients over a fairly long period; the potential drawback is that they may not release enough of their principal nutrient at a time to give the plant what it needs for best growth. Because organic fertilizers depend on soil organisms to break them down to release nutrients, most of them are effective only when soil is moist and soil temperature is warm enough for the soil organisms to be active. Cottonseed meal is a by-product of cotton manufacturing. As a fertilizer, it is somewhat acidic in reaction. Formulas vary slightly, but generally contain 7 percent nitrogen, 3 percent P2O5, and 2 percent K2O. Cottonseed meal is readily available to plants in warm soils, and there is little danger of burn. Cottonseed meal is frequently used for fertilizing acid-loving plants such as azaleas, camellias, and rhododendrons.

1.2.3.4 Sewage sludge is a recycled product of municipal sewage treatment plants. Two forms are commonly available: activated and composted. Activated sludge has higher concentrations of nutrients (approximately 6-3-0) than composted sludge, and is usually sold in a dry, granular form for use as a general purpose, long-lasting, non-burning fertilizer. Composted sludge is used primarily as a soil amendment and has a lower nutrient content (approximately 1-2-0). There is some question about the long-term effects of using sewage sludge products in the garden, because heavy metals, such as cadmium, are sometimes present in the sludge. However, all sewage sludge must be analyzed for heavy metals and meet a regulatory standard, such as US EPA standards before it can be sold for soil applications.

1.2.3.5 Compared to synthetic fertilizer formulations, organic fertilizers contain relatively low concentrations of actual nutrients, but they perform other important functions which the synthetic formulations do not. Some of these functions are: increasing organic content of the soil; improving physical structure of the soil; and increasing bacterial and fungal activity.

1.2.3.1 Fertilizers Combined with Pesticides

(1) The major reason for buying a fertilizer combined with a pesticide is convenience. It is very convenient to combine everything you need in one application, but it is also very expensive. The problem is that the timing for a fertilizer application often does not coincide with the appearance of a disease or an insect problem. And, in the case of a number of turf grass diseases, a primary cause of disease infestation is merely a lack of proper fertilizer.

(2) A fertilizer-insecticide combination, when applied at the proper stage of a pest’s life-cycle, can do an adequate job of controlling the turf pest while also giving the grass "a shot in the arm" to help its recovery. However, fertilizers with pesticides intended for use with turf or ornamentals should

not be used in the vegetable garden where it may contaminate food crops. Always read the label carefully.

1.2.4 Fertilizer Formulation

1.2.4.1 Fertilizers come in many forms. Different formulations are made to facilitate types of situations in which fertilizer is needed. Packaging on all formulations must show the amount of nutrients contained, and sometimes it tells how quickly a nutrient is available. Some of the formulations available to the homeowner are: water-soluble powders, slow-release pellets, slow-release collars or spikes, liquids, tablets, and granular solids.

1.2.4.2 Liquid fertilizers come in a variety of different formulations, including complete formulas and special types that offer just one or two nutrients. All are made to be diluted with water; some are concentrated liquids themselves, others are powder or pellets. Growers of container plants often use liquid fertilizers at half the recommended dilution twice as frequently as recommended so that the plants receive a more continuous supply of nutrients.

1.2.5 Applying Fertilizer

Computing the amount of fertilizer needed for a given area is rather tricky at first, but after a few times, this becomes second nature.

2.0 FERTILIZER APPLICATION

2.1 FACTORS

Soil type dictates the frequency of fertilizer application. Sandy soils require more frequent applications of nitrogen and other nutrients than do clay-type soils. Other factors affecting frequency of application include the type of crop, the level of crop productivity required, frequency and amount of water applied, and type of fertilizer applied and its release rate.

2.1.1 Timing

2.1.1.1 The type of crop influences timing and frequency of application since some crops are heavier feeders of particular nutrients than others. A general rule of thumb is that nitrogen is for leafy top growth; phosphorus is for root and fruit production; and potassium is for hardiness, disease resistance, and general durability.

2.1.1.2 Proper use of nutrients can control plant growth rate and character. Nitrogen is the most critical nutrient in this regard. If tomatoes or squash are fertilized heavily with a nitrogen fertilizer into the summer, the plants may be all vine and no fruit. If slow-release fertilizers or heavy amounts of manure are used on crops that form fruit or vegetables, leaf and vine growth will continue into late summer, and fruit and vegetable development will occur very late in the season.

2.1.1.3 The following suggestions about groups of garden plants are given as general guides. Gardeners should be aware that individual species within these groups vary considerably. After each group of plants, the need for the primary nutrients (nitrogen, phosphorus, and potassium) is indicated as high, medium, or low.

Table 3 Primary Nutrient Need by Plants

Plant Group	Primary Nutrient (N-P-K) Need
Vegetables	High
Herbs	Medium to Low
Lawns	Medium to High
Fruits	Medium
Annual flowers	Medium
Perennial flowers	Medium to Low
Deciduous shrubs	Medium to Low
Evergreen shrubs	Low
Deciduous shade trees	Medium to Low
Evergreen shade trees	Low

2.2 APPLICATION METHODS

2.2.1 There are different methods of applying fertilizer depending on its formulation and the plant needs.

(a) Broadcasting

2.2.2 A recommended rate of fertilizer is evenly spread over the growing area and left to filter into the soil or is incorporated into the soil with a rototiller, or spade, with irrigation water. Broadcasting can be used over large garden areas or when time or labor is limited.

This method should not be used in areas close to the Lake and wetland shoreline.

(b) Banding

2.2.3 Narrow bands of fertilizer are applied in furrows several inches from the seeds or plants. Banding is one way to satisfy the needs of many plants phosphorus as the first roots develop. When fertilizers are broadcast and worked into soil, much of the phosphorus is locked up by the soil and is not immediately available to the plant. By concentrating the phosphorus in a band, the plant is given what it needs even though much of the phosphorus stays locked up.

(c) Side-Dressing

2.2.4 Dry fertilizer is applied as a side dressing after plants are up and growing. Scatter fertilizer on both sides of the row 6 to 8 inches from the plants. Rake it into the soil and water thoroughly.

(d) *Foliar Feeding*

2.2.5 Foliar feeding is used when insufficient fertilizer was used before planting; a quick growth response is wanted; micronutrients (such as iron or zinc) are locked into the soil; or when the soil is too cold for the plants to use the fertilizer applied to the soil. Foliar-applied nutrients are absorbed and used by the plant quite rapidly.

3.0 GUIDELINES

3.1 Landscaping design considerations should site plants according to their fertilizer demand:

- High demand plants should be located further away from lake/wetland edges.
- High demand plants should not be located on slopes to minimise fertilizer loss by runoff. Alternatively, the area for fertilizer application of such plants should be depressed to contain fertilizer applications.
- Slow-release fertilizers should be preferred over other types of fertilizers. It is recommended that the soluble Phosphorus should not be used within the Catchment area. Instead the insoluble form of Phosphorus should be used if necessary.
- Correct fertilizer loadings should be applied through calculation, to prevent wastage and subsequent loss through runoff.
- Frequent, small applications are preferred to few, large applications.
- Grass clippings should be left on the turf to recycle nutrients instead of being swept away.

4.0 REFERENCES

1. Arizona Cooperative Extension (1998), Arizona Master Gardener Manual. College of Agriculture, The University of Arizona.

APPENDIX B

PUTRAJAYA LAKE CATCHMENT

PESTICIDE USE GUIDELINES

APPENDIX B

PUTRAJAYA LAKE CATCHMENT PESTICIDE USE GUIDELINES

1.0 THE PESTICIDE REGISTER

1.1 The proper use of pesticides will ensure their effectiveness while ensuring minimum impact to safety and the environment.

1.2 A register of pesticides used, the amount and area of application, and the persons applying the pesticide should be maintained.

1.3 This will allow for monitoring of the amount and area the pesticides are being applied.

1.4 The **Pesticide Register** should be given to two parts:

a. Information on the pesticide characteristics
b. Information on application

1.5 The Register should contain the following information:

a. Pesticide characteristics
Pesticide name and formulation
Manufacturer
Safety precautions
Environmental hazard/precautions
Toxicity Class
Storage Location
Person responsible for application control

b. Application information
Area applied
Quantity applied
Date applied

1.6 The pesticide label can provide information on the pesticide characteristics. The label information should be recorded and normally carries the following type of information:

1. Brand name
Type of formulation

2. Ingredient statement
List of the names and amounts of the active and inert ingredients.

3. Common name and chemical name

4. Net contents
   Volume in the container.

5. Name and address of manufacturer
   The maker or distributor of a product, the name and address of the company on the label.

6. Registration number
   A registration number must be on every pesticide label.

7. Precautionary statements
   A warning or hazard section or a title like "Hazards to Humans and Domestic Animals" will explain the ways in which the product may be poisonous to man and animals. It should describe any special steps necessary to avoid poisoning, such as the kind of protective equipment needed. If the product is highly toxic, this section will inform physicians of the proper treatment for poisoning.

8. Environmental Hazards
   This section should tell how to avoid damage to the environment. Some examples are: "This product is highly toxic to bees exposed to direct treatment or residues on crops." "Do not contaminate water when cleaning equipment or when disposing of wastes," and "Do not apply where runoff is likely to occur."

9. Physical and Chemical Hazards
   Lists other specific fire, explosion, or chemical hazards that the product may have.

10. Toxicity Class, Signal Words and Symbols
    Some pesticides may be hazardous to people. A Signal Word and Symbol (Table 1) is often used on the label. Some toxicity doses are given in Table 2.

11. Statement of practical treatment
    If swallowing or inhaling the product or getting it in the eyes or on the skin would be harmful, the label should contain emergency first aid measures and states types of exposure requiring medical attention. The pesticide label is the most important information you can take to the physician when someone has been poisoned. Without the label, it is difficult for the physician to help.

12. Directions for use
    The instructions will explain several important items.
    - The pests the product will control
    - The crops, animals, or other item the product can be used on safely
    - How the product should be applied
    - How much to use

Where and when the material should be applied
Application to harvest periods

13. Storage and disposal directions
Every pesticide should be stored and disposed of correctly. This section will tell you how to store and dispose of the product.

Table 1 Signal Words and Symbols

Word	Toxicity	Human Lethal Dosage	Symbol
Danger	High	taste to a teaspoon	skull and crossbones; Poison
Warning	Moderate	teaspoon to a tablespoon	none
Caution	Low	ounce to more than a pint	none

2.0 TOXICITY AND PERSISTENCE OF PESTICIDES

2.1 The least toxic and least persistent chemicals should be used for any job. The selection must be based on the nature and extent of infestation.

2.2 Some pesticide toxicity information is given in Table 2.

2.3 Herbicide persistence information based on temperate climate conditions are given in Table 3.

3.0 PESTICIDES AND WATER QUALITY

3.1 The use of pesticides affect water quality through the introduction of non-natural materials, even in small doses. An important factor to water quality is the potential for the pesticide to be washed off the applied plants. Therefore the selection of chemical to use would prefer the one least likely to run off during rain events.

3.2 Runoff potential of herbicides, insecticides and fungicides are given in Tables 4, 5, and 6.

Table 2 **Pesticide Toxicities** *(from Pesticide Information and Training Office, copyright University of Arizona, January 1996)*

Trade Name	Class	Active Ingredient	LD_{50} (rat, oral, mg/kg)
Toxicity Level I B Danger (Oral LD_{50} up to 50 mg/ml)			
Rodine	ROD	red squill	0.7
Temik	I	aldicarb	1
Phosdrin	I	mevinphos	3 - 12
Vydate	I	oxamyl	5.4
Penncap-M	I	methyl parathion	6
Cymag	ROD	sodium cyanide	6.4
Endrin	I	endrin	7 - 15
Furadan 4F	I	carbofuran	8
Dyfonate	I	fonofos	8 - 17.5
Hybrex	ROD	fenrazidon-potassium	25
Aldrin	I	aldrin	38 - 67
Nicotine	I	nicotine	50 - 60
Toxicity Level II B Warning (Oral LD_{50} from 50 to 500 mg/kg)			
Methyl bromide	FUM	methyl bromide	65
DDT	I	DDT	113
Derris	I	rotenone	132-1500
Gramoxone Extra	H	paraquat	150
Lorsban	I	chlorpyrifos	163
Caffeine		caffeine	192
Pyrocide	I	pyrethrum	200
Dimethoate	I	dimethoate	235
Sevin	I	carbaryl	246 - 283
Ammo	I	cypermethrin	250
Capture	I	bifenthrin	375
Copper-Z 4/4	F	copper sulfate	472

Table 3 **Persistence of biological activity at the usual rate of herbicide application in a temperate climate with moist, fertile soils and summer temperatures** *(Water Quality Handbook for Nurseries, E-951, Oklahoma Cooperative Extension Service, Division of Agricultural Sciences and Natural Resources, Oklahoma State University Ch 6)*

1 Month or Less		1-3 Months		3-12 Months		Over 12 Months[3]
Acifluorfen	Fluorodifen	Bifenox	Metolachlor	Alachlor	Fluometuron	Borates
Acrolein	Glyphosate	Bromoxynil	Naptalam	Ametryn	Fluridone[4]	Bromacil
Amitrol	Fluazifop	Butachlor	Pebulate	Atrazine	Hexazinone	Chlorates
AMS	Fenoxaprop	Butylate	Prometryn	Benefin	Isopropalin	Chlorsulfuron
Barban	Metham	Chloramben	Propachlor	Bensulide	Imazamethabenz	Fenac
Bentazon	Methyl bromide	Chlorpropham	Proham	Buthidazole	Imazaquin	Fluridone[5]
Benzadox	MCPA	Cycloate	Pyrazon	Chlorimuron	Imazethapyr	Hexaflurate
Cacodylic Acid	MCPB	Desmedipham	Siduron	Clomazone	Metribuzin	Imazapyr
Chloroxuron	Molinate	Diallate	TCA	Clopyralid	Monuron	Karbutilate
Dalapon	MSMA	Diphenamid	Terbutryn	Cyanazine	Napropamide	Picloram
2,4-D	Nitrofen	EPTC	Thiobencarb	Cyprazine	Norflurazon	Prometon
2,4-DB	Paraquat[6]	Linuron	Triallate	DCPA	Oryzalin	Tebuthiuron
Diclofop	Phenmedipham	Mecoprop	Vernolate	Dicamba	Oxyfluorfen	Terbacil
Diquat6	Propanil	Methazole		Dichlobenil	Pendimethalin	2,3,6-TBA
DSMA	Sethoxydim			Difenzoquat	Perfluidone	
Endothal				Dinitramine	Pronamide	
				Diuron	Propazine	
				Ethalfluralin	Simazine	
				Fenuron	Sulfometuron	
				Fluchloralin	Trifluralin	

[1]These are approximate values and will vary.
[2] At higher rates of application, some of these chemicals may persist at biologically active levels more than 12 months.
[3]At lower rates of application, some of these chemicals may persist at biologically active levels for less than 12 months.
[4] In water.
[5] In soil.
[6] Although diquat and paraquat molecules may remain unchanged in soils, they are absorbed so tightly they become biologically inactive.

Table 4 **Herbicide water quality data** *(Water Quality Handbook for Nurseries, E-951, Oklahoma Cooperative Extension Service, Division of Agricultural Sciences and Natural Resources, Oklahoma State University Ch 6)*

Herbicide Common Name	Relative Runoff Potential	Relative Ground Water Leaching Potential	Half-Life in Days
Diquat	Small	Small	N/A
Glyphosate	Large	Small	47
Pendimethalin	Large	Small	90
Napropamide	Large	Medium	70

Table 5 **Insecticide water quality data** *(Water Quality Handbook for Nurseries, E-951, Oklahoma Cooperative Extension Service, Division of Agricultural Sciences and Natural Resources, Oklahoma State University).*

Systemic Insecticide Common Name	Relative Runoff Potential	Relative Ground Water Leaching Potential	Half- Life in Days
Malathion	Small	Small	1
Acephate	Low	Low	3
Dimethoate	Small	Medium	7
Carbaryl	Medium	Small	10
Diazinon	Medium	Large	30
Chlorpyrifos	Large	Small	30
Dicofol	Large	Small	60
Propargite	Large	Small	l56

Table 6 **Fungicide water quality data** *(Water Quality Handbook for Nurseries, E-951, Oklahoma Cooperative Extension Service, Division of Agricultural Sciences and Natural Resources, Oklahoma State University).*

Fungicide Common Name	**Relative Runoff Potential**	**Relative Ground Water Leaching Potential**	**Half-Life in Days**
Thiophanate-methyl	Small	Medium	10
Ferbam	Medium	Medium	17
Vinclozolin	Medium	Medium	20
PCNB	Large	Small	21
Triforine	Medium	Small	21
Triadimefon	Medium	Medium	26
Chlorothalonil	Large	Small	30
Manozeb	Large	Small	70
Metalaxyl	Small	Medium	70
Propiconazole	Medium	Medium	100
Etridiazole	Large	Small	103
Fenarimol	Medium	Small	360

4.0 HOME AND GARDEN

4.1 A large proportion of pesticide application may come from residents with gardens. To reduce incorrect or inappropriate use of pesticides information on garden management should be made available and importance of control must be stressed to residents.

4.2 There are many books and manuals available for the home gardener. The recommendations given here have been adapted from Water Quality Handbook for Nurseries, E-951, Oklahoma Cooperative Extension Service, Division of Agricultural Sciences and Natural Resources, Oklahoma State University. It should be the minimum advice given the home owner.

Best Management Practices for Home & Garden Pesticide Use

A. When selecting pesticide/herbicide to purchase:

1. Use a pest control method only when that method will prevent the pest from causing more damage than is reasonable to accept.

2. Consider other pest control methods

   Cultural
      Keep the turf vigorous to compete against weeds.
      Practice careful water management.
      Use tillage to remove weeds if possible.
   Mechanical
      Hand remove individual weeds/other pests.
   Sanitation
      Plant weed free seed.
   Host resistance
      Plant disease-resistant turf grass and trees.
   Integrated Pest Management
      observe, monitor, decide

3. Buy only in small quantities that will be used in a short period of time.

4. Choose the least toxic pesticide. Note the signal word on the label (in increasing toxicity): caution, warning, or danger.

B. Mixing and application:

1. Read and follow pesticide label instructions.

2. Apply pesticides only to sites identified on the label. Label sites where pesticides are being applied.

3. Always measure accurately and calibrate. Use only the amount needed. Do not prepare excess amounts. The whole mixture should be used in a single application.

4. Mix pesticides together only when allowed on the label.

5. Keep children and pets away from treated areas until sprays are dry or dusts/granules have settled.

6. Avoid spray drift, do not apply sprays on windy days.

7. Don't eat or smoke while applying pesticides.

8. Keep application equipment in good condition.

9. See the label for appropriate pesticide protective clothing and/or equipment.

10. Do not allow runoff or drift into storm sewers or water.

11. Follow label directions for cleanup of equipment.

12. Rinse sprayers and empty liquid pesticide containers with water, apply rinse water to the labelled application site. Do not rinse down the drain.

13. Be aware that irrigation water can carry pesticides (and fertilizers) down through the soil, especially sandy soils, and into the ground water. Do not over-water.

C. Pesticide storage:

1. Store pesticides only in the original, labeled containers. Do not store in empty unlabelled bottles or containers.

2. Store in a secure, locked, ventilated area away from children and pets.
3. Store pesticides separate from food, feed or eating/cooking utensils.

4. Protect pesticides from extremes in temperature and keep them dry.

5. When storing on shelves, store dry products above liquid pesticides.

D. Disposal and spills:

1. The best disposal method is to use the pesticide according to the label.

2. Never re-use pesticide containers for any purpose.

3. Never pour pesticides down the drain or into the toilet.

4. Follow additional guidelines as printed on the label.

5. If a spill occurs, soak it up immediately with soil or vermiculite. Spread these materials over a wide area to a labelled application site. Do not wash with water if spilled on concrete, it spreads the spill.

E. Personal safety:

1. Be aware that pesticide exposure can occur through the skin (includes eyes), by mouth, and by inhalation. Exposure by skin is the most common and easiest to prevent.

2. Wear long sleeved shirt and trousers when applying pesticides.

3. Wear pesticide gloves (nitrile, neoprene, or rubber) as guided by the label. Do not wear latex gloves. These may dissolve in the pesticide base.

4. Goggles prevent eye exposure, especially during measuring and mixing operations.

5. Wash immediately after each application.

6. Launder pesticide-contaminated clothing separately from regular laundry in hot water with heavy duty liquid detergent. After washing, run the washing machine a second time with detergent without clothes.

When Applying Pesticides

- Consider the vulnerability of the site; be sure that weather and irrigation will not increase the risk of water contamination.
- Evaluate the location of water sources.
- Read and follow pesticide label directions.
- When possible, use the pesticide with the least potential for surface runoff and leaching.
- Store pesticides properly.
- Make sure pesticide containers do not leak.
- Use IPM practices.
- Calibrate all pesticide application equipment after at least every third use.
- Prevent backflow during mixing operations by use of a mechanical anti-siphoning device or an air gap.
- Triple or pressure rinse pesticide containers upon emptying and pour rinsing water into spray tank.
- Always mix, handle, and store pesticides at least 30 m from water wells, water bodies.
- Do not apply pesticides when conditions are likely to produce runoff or excessive leaching; for example before rain is likely to occur, or before watering.
- Do not spray pesticides on windy days (winds in excess of 10 mph).
- Prevent pesticide spills and leaks from application equipment.
- Leave buffer zones around sensitive areas such as wells, irrigation ditches, ponds, streams, drainage ditches, septic tanks, and other areas that lead to ground or surface water.
- Do not water pesticide-treated areas immediately after application unless indicated on label instructions.
- Dispose of excess pesticides by applying them to labeled pesticide application sites.

5.0 REFERENCES

1. Oklahoma Cooperative Extension Service (1998). Water Quality Handbook for Nurseries, E-951, Division of Agricultural Sciences and Natural Resources, Oklahoma State University.

2. Arizona Cooperative Extension (1998). Arizona Master Gardener Manual, College of Agriculture, The University of Arizona.

APPENDIX C

PUTRAJAYA LAKE CATCHMENT GUIDELINES FOR THE DEVELOPMENT OF MINI WETLANDS

APPENDIX C

PUTRAJAYA LAKE CATCHMENT
GUIDELINES FOR THE DEVELOPMENT OF MINI WETLANDS

1.0 PURPOSE OF GUIDE

The purpose of this guideline is to assist in the creation or conversion of detention ponds in the Putrajaya Catchment into mini-wetlands.

2.0 FUNCTIONS OF MINI-WETLANDS

2.1 The primary intended function of the creation of mini-wetlands is to improve water quality by invoking conditions for natural water treatment processes. Mini-wetlands can be intended as public open spaces but the public should have limited access to them to ensure ecological preservation. By virtue of limited access, the wetland will also become a refuge for nature.

2.2 In the Putrajaya Catchment, the function and usefulness of mini-wetlands are almost the same as for riparian parks, lake valley parks and retention ponds to be provided within the Putrajaya Federal Government Administrative Centre Peripheral areas (refer to Urban Design Analysis and Strategy). Nonetheless, there will be differences in the physical shape, size and depth of mini-wetlands with those of parks and retention ponds proposed in the Urban Design Masterplan. Despite these physical spatial differences, the basis of species selection and planting strategy at various zones of wetlands can be based on the guidelines spelt out in the Putrajaya Urban Design Masterplan.

3.0 DESIGN FACTORS

3.1 A number of factors affect the functions of wetlands for water quality treatment. They are:

1. Mini-wetlands are generally shallow water bodies, of 1 to 4 m depth, compared to detention ponds.

2. Longer water retention times in the ponds allow for increased treatment capacity.

3. The vegetation type selected should be indigenous species that are suitable for the substrates at the bottom of the pond and its littoral zone. Both functional and structural features should be considered in the selection. Examples of the functional features are the nutrient uptake demand and capacity by the plants and trees and their microbiological carrying capacity. Examples of the structural attributes are the height and shade efficiency and their refuge value for fish and other invertebrates.

4. When creating artificial ponds, land-based biomass and topsoil has to be removed from the detention pond. Care should be taken to ensure that no

such biomass are left at the bottom of the pond otherwise they will degrade under anaerobic conditions and result in noxious smells and poor water quality as nutrients are released.

5. A heterogeneous system, with more than one habitat and associated vegetation types is necessary to improve the treatment capacity of the mini-wetlands. Mini-wetland systems are temporally and spatially dynamic. As such the uniformity of vegetation may not provide the resilience required to cope with the variability in the environment of the waters in the ponds.

3.2 The recommended habitat types, vegetation and fish species for the mini-wetlands are described below.

4.0 DEVELOPMENT RECOMMENDATIONS

4.1 Habitat Types

4.1.1 Detention ponds are usually deep. Figure C.1 shows the typical cross section of a wetland. There are three distinct habitat types within it. To create a mini-wetland in a detention pond it is necessary to create the three habitat types within the pond. They are the :

- main pond habitat, deeper than 3 m;
- deep and shallow marsh zones, between 1-3 m;
- swamp forest zone, i.e. the terrestrial habitat at the land-water interface, where the soil is moist and saturated.

4.1.2 The presence of the three zones will allow a heterogeneous system to be established, allowing for sedimentation processes in the deep pond, nutrient uptake and habitat formation in the wet marsh and moist forest zones.

4.2 Vegetation Types

4.2.1 Species selection for the swamp forest zone or high shore line (permanently moist ground) of the mini-wetland shall be such as to comprise of mixed tree species of various characters such as large coloured foliage, domed and umbrella shaped canopies, fragrant and flowering trees. They range from lower-storey species, middle-storey species and upper climax species. They will provide characteristics such as shade zone, wildlife refuge, woodland, good buffer/screening and water edging. The planting shall be of a woodland character.

4.2.2 The species to be selected should have the following characteristics:

- Compatible with immediate upland land use and guidelines of Urban Design Masterplan for Putrajaya;
- Vegetation to be of indigenous origin having ornamental value;
- Ability to absorb nutrients;
- Grow and propagate without fertiliser;

- Oxygenate water and sediments;
- Provide suitable aquatic fauna habitat, their potential for sustainability over time and their ornamental value;
- Provide water shading, cooling and diversity of habitat types for water birds;
- Create a natural transition of vegetation types.

4.2.3 In the Perbadanan Putrajaya area, the species selected should be compatible with any adjoining riparian parks, lake valley parks, and retention ponds, as proposed in the Urban Design Analysis and Strategy.

4.2.4 Tree species with coloured foliage could include *Eleocarpus*, *Erythrina*. Species like *Alstonia* can provide large foliage character. *Enterolobium* can provide shade with its umbrella-shaped crown. Suitable trees or shrubs with fragrant flowers include *Michelia* and *Gardenia.*

4.2.5 To ensure effective pollutant treatment by the vegetation (through biofiltration) in the mini-wetlands, careful selection of the vegetation is necessary. Table C.1 gives the recommended vegetation types and species for the various zones in a mini-wetland.

4.2.6 Even though free floating and submergent aquatics can achieve excellent nutrient removal efficiencies due to their fast growth and high biomass turnover they are not recommended because their fast growth can choke off the entire mini-wetland in a very short time. Thus, rooted emergent aquatic macrophytes are recommended since they possess the following positive characteristics:

i. High biomass carrying capacity
ii. High nutrient uptake capacity
iii. Provide refuge for fish, aquatic invertebrates and birds
iv. High microbial decomposition

4.2.7 The forested swamp is recommended because it provides a long term nutrient sink in the mini-wetland due to its biomass size and low rate of litter decomposition. It also provide shading benefits to the open water zones reducing light attenuation, promotes phytoplankton growth and water cooling which are beneficial to fishes and other aquatic organisms. Also, structurally the forested swamp provides an attractive visual height and critical habitats for a wide range of fauna and birds.

4.2.8 Phytoplankton biomass may increase after the construction of the mini-wetland. Thus, control of the phytoplankton biomass is important and can be carried out through the appropriate selection of fish and zooplankton feeders.

Table C.1 Recommended Vegetation Types and Species for the Mini-Wetlands

Mini-Wetland Zone	Vegetation Types	Nature of zone	Key Species
Forest Swamp	Trees	Permanently Moist to Water Logged Soils, Zone of Intermittent Flooding	*Alstonia spatulat* *Dipterocarpus* Spp *Dipterocarpus hasselti* *Eugenia* Spp. *Eugenia chloroleuca* *Eleocarpus* sp. *Erythrina* sp. *Enterolobium* sp. *Ficus microcorpa* *Gardenia carinata* *Ixora javanica* *Melaleuca* Spp. *Saraca thaipingiensis* *Shorea macroptera* *Shorea* Spp.
Shallow Macro-phyte Zone	Rooted Emergent Macro-phyte	Shallow Permanent Water/ Shallow Marsh	*Cypera* Spp. *Eleocharis* Spp. *Lepironia* Spp. *Lepironia articulata* *Saccharum* sp. *Scirpus grossus* *Scleria* sp *Phragmites karka*
Open Water	Rooted Emergent	Deep Water >3m	*Ipomoea reptans*/*aquatica* *Nelumbo nucifera* (Lotus) *Nymphnea lotus*

4.3 Fish Species

4.3.1 Fish should be introduced into the mini-wetland to contribute to the maintenance of good water quality in the mini-wetland. The following criteria should be followed when selecting the fish species:

- Indigenous species
- Pelagic species
- Rare and endangered/threatened species
- Sport fish
- Carnivorous and insectivorous species

4.3.2 The recommended fish species for the mini-wetlands is given in Table C.2

Table C.2 Recommended Fish Species for the Mini-Wetlands

Species	Ecological Attributes
Puntius tetrazona (Tiger Berb)	Predate mosquito and zooplankton feeder. High ornamental value
P. gonionotus	Same as above
P. schwanenfeldii	Good sport and ornamental fish
Betta splendens	Feed on phyto- and zooplankto, good ornamental value
Rasbora Spp.	Predate mosquito larvae, insects and some aquatic plants
Trichogaster pectoralis	Control algal production
Leptobarbus hoevenii	Phytoplankton feeder also feeds on aquatic plants. Ornamental fish species
Channa striata	Carnivorous and predate mosquito larvae.

5.0 WETLANDS MANAGEMENT

5.1 Best Management Practices

Recommendations of the Best Management Practices (BMP) to sustain the desired ecological balance for the Putrajaya Lake and its associated wetlands are given below.

5.2 Wetland Plants

5.2.1 For the wetland plants the following factors need to be considered:

- Plant harvesting for die-off, overcrowding and disease to plug further damage to health plants;
- Planting density (to replenish the harvested plants) to be low to very moderate to prevent excessive growth and reaching carrying capacity;
- Pest attacks to be eliminated by applying environmentally friendly pesticide and biological control;
- Unwanted aquatic weeds must be uprooted from the cells. This will be done by manual weeding, applying herbicide (environmentally friendly) and maintaining required water level in the wetland cells;
- Optimum water level (as designed) must be maintained in the wetland cells to control unwanted aquatic weeds and make available adequate nutrients and pollutants to wetland plants;
- For replanting *Scleria* sp., which is less foliaceous and resistant to fluctuating environment can be given priority. However, the planting density

will be less than 6 sp/m^2;

- The colour of the plant leaves should be monitored for chlorosis and growth;

- Water circulation from upstream to downstream to be maintained to reduce plant litter at the substratum. To reduce plant litter, stocking of detritivorous and omnivorous fish species are recommended;

- Planting of rare and endangered wetland/terrestrial plants should be encouraged;

- Weekly monitoring of wetland plants and take immediate appropriate action to prevent further damage or secondary infection to wetland plants;

- Monthly management meeting to review effectiveness of measures taken to maintain healthy plants in wetland cells.

5.2.1 Plant Harvesting

5.2.1.1 Plant die-off, due to overcrowding, pest infestation and weed's invasion in the wetland cells, is common and expected. It should not interrupt the ecological cycle as each wetland cell has its own microbial carrying capacity. However, if the die-off is significant involving large planting area, there will be need for harvesting. Thus, routine harvesting of senescent plants due to disease or overcrowding or to reasons unexplained, is very appropriate and this exercise to be completed during drought period rather than monsoon.

5.2.1.2 Plant harvesting will have environmental impacts on water quality and fish and invertebrates and it must be addressed properly. One of the options to maintain the water quality, is to raise temporarily the stop logs in the weir to increase retention time by increasing volume. This will allow for the sediments to settle at the bottom. The rise in the stop logs will temporarily stop water flow into the downstream.

5.2.2 Planting Density

Planting density is to be as low as possible so as to allow for plant growth and natural propagation. The recommended density for transplanting the harvested cells is as follows:

Scleria sp. - <6 plants/m^2

Others, such as *Phragmites* sp. *Lepironia* sp. and *Scirpus* sp. - <10 plants./m^2

5.2.3 Species Selection

5.2.3.1 Currently there is limited information on the ability of an individual wetland species to uptake of particular nutrients at a particular aquatic habitat type. The wetlands at Putrajaya represent an excellent opportunity for research into this area.

5.2.3.2 It is generally known that Nitrogen, Phosphorus and Potassium are the three major nutrient elements required for the growth and propagation of plant species including those of wetland plants. But the intricate physiology of nutrient uptake and cellular absorption are little known. Especially very little is known particularly on the tropical and equatorial wetland plants with some information available from temperate regions. However, the information available on the temperate wetland plants may be of little relevance to the tropical wetland species because of the different rates and annual pattern of growth, and the temperature difference which may affect the rates of the biochemical processes themselves. Nevertheless, some general information which may be applicable of the tropical wetlands which are shown in Table C.3.

Table C.3 Plant species and nutrient uptake

Species	Information Available
Phragmites karka	Ability to polish sewage effluents
Lepironia articulata	High nutrient absorber
Saccharum sp.	Good nutrient absorber, shading and refuge for fish
Scirpus grossus	Good nutrient absorber

5.2.3.3 Although other wetland plant species are well known to have ability in nutrient uptake in cleaning up of euthrophicated lakes, ponds, reservoirs and marshland, quantitative field experiments have not been done yet. As such precise information are not available.

5.2.3.4 For the shoreline, *Scleria* sp. is less foliaceous and fast growing. It is relatively more resistant than other species and withstands more water level fluctuation in the cells. As a replacement of harvested species, it can be given priority.

5.2.4 **Control** of **Unwanted Aquatic Weeds**

5.2.4.1 Weeds are the major problems in the non-inundated or improperly inundated cells than in the inundated ones. Weeds are competitive and fast growing compared to wetland plants. They are resistant to harsh environment. Common weeds in the wetland are Mimosa, *Pudica* sp. *Galinsoga* sp. *Rhyncospora* sp. *Fimbristylis* sp. and *Limnocharis* sp.

5.2.4.2 The following steps are to be taken:

- Continuous monitoring
- Manual weeding to be done periodically and consistently in all wetland

cells. The exercise has to be limited to noxious and exotic species.

- Maintain the required water level so that weeds are submerged under water. This will prevent further germination of seeds and seedlings.
- Manual weeding of oil palm seedlings.

5.2.4.3 A successful way of removal of unwanted aquatic weeds is by the use of biodegradable herbicides which would have little effect on fish and other invertebrates. The pesticide BMP can be consulted for appropriate herbicides. Regular manual weeding is the best non-polluting method.

5.2.5 Pest Infestation

5.2.5.1 Pest problems have been documented at early stage in the Putrajaya Wetlands (Putrajaya Constructed Wetlands, Advisory Report #8, Wetland International - Asia Pacific). Disease attacks on some wetland plants in UN and UW cells are also found in the present study. *Phragmites karka* and *Scirpus grossus* were found to have been attacked by aphids and stem borer respectively. This was found sporadically in some cells. The problems are, however localised and can be addressed effectively. The following steps are to be considered for action immediately.

1. To develop an Integrated Pest Management Techniques (IPM). IPM is a well-established pest management system whereby pests are killed at a threshold level without having any impact on non-target organisms.

2. Immediate harvesting of the infected plants and transplanting with new plants. Planting density must not exceed 10 sp./m^2 for species other than Elephant Grass. *Scleria* can be planted more than *Phragmites karka* due to latter's resistance to environmental constraints.

3. Biological control method using natural predators of pest and insects. Biopesticide, *Bacillus thuringinesis* can control the pests namely caterpiller leaf rollers (*Craphalocrocis medinalis*) and rice step borer, *Scirpophaga incertulas*.

5.2.6 Water Level Management

Maintenance of required water level is extremely important for survival and propagation of wetland plants. Water level varies with rate of establishment of wetland plants. Shortage or lack of water can put wetland plants under stress and reduced plant vigour. It increases the chance of secondary attack by pests. In such cases water levels should be increased to control unwanted aquatic weeds at the fringe of the marsh zone and to make available adequate nutrients and pollutants to a variety of wetland plants.

5.2.7 Monitoring Plant Performance

5.2.7.1 It is expected that a plant biologist/botanist or horticulturist will be involved in the vegetation monitoring. The following points have to be considered and provide biological indicators of plant health:

1. The colour of plant leaves should be monitored;
2. Leaves should be observed for chlorosis;
3. Removal of plant litter manually. Plant litter deposited at the bottom of the wetland arms can be removed by suction dredging. The disadvantage, however, is that it can dislodge the roots of the wetland plants.

5.2.7.2 Removal of plant litter at the substratum can be achieved by ensuring the following:

1. Water circulation from upstream to downstream via wetland cells and primary lake;
2. Establishment of roots of wetland plants into the substratum;
3. Stocking more detritivorous, and omnivorous fish species in the wetland cells.

5.2.8 Plant Nursery

Supply wetland plants as, and when, necessary, to replenish the harvested plants is crucial to operation and management of wetland system. The outdoor nursery should be ideally located within the Putrajaya wetland at a strategic location so that they can be supplied readily in any affected wetland arms. The wetland nursery used by the wetland contractors is suitable.

5.2.9 Wetland Plant Monitoring

Long term monitoring and management are important for maintenance of a healthy wetland system. Weekly supervision of general health of all dominant plant species in the wetland cells is to be undertaken. Immediate actions are to be taken for remedy if incidences of any of the following are apparent:

1. Lack/shortage of water in any of the wetland cells; water levels should be in the region of 0.3 to 2 m for aquatic plant growth;
2. Overcrowding of any of the species in the cells that have caused stress, pest infestation and reduced plant vigour resulting in the stunting of growth;
3. Insect attack of significant proportion in any of the species in the wetland cells;
4. Illegal poaching on wetland plants for hunting purpose.

5.3 Fish Community

The objective of fish stocking is to control mosquito larvae, maintain good water quality and support sport and recreational fishery. Nevertheless, the overgrowth of species like Tilapia can be a cause of concern as it will dominate other species present. The following control measures are necessary:

5.3.1 Control of Undesirable Species

5.3.1.1 Species of Tilapia is always a nuisance to the aquatic system for its fast growing nature which if not controlled will affect other fish species. They can be controlled by:

1. Fish sampling using netting (cast and gill netting) and scooping
2. Angling and sport fishing
3. Biological control by introducing more predatory sport and game fish.

5.3.1.2 Some species need to be controlled at the early stage. Generally, the Grass carp, *Ctenopharyngodon idellas*, is the herbivore of concern. Its daily intake of grass is expected to be three times its body weight. Thus it should not be stocked in the initial 2-3 years. Other members of the carp family are not herbivores. Once the wetland plants are established, the Grass Carp can be introduced in deeper waters, at low numbers, so as not to destroy the plant leaves of the Primary Lake and Central Wetlands. In addition, cut grass leaves can be a food source for the Grass Carp population in the water body.

5.3.2 Routine Fish Sampling and Restocking

Routine fish sampling is to be conducted to realise the level of fish recruitment and adaptability to a new habitat. Exact density and availability (comprehensive inventory) will not be known at this stage. However, based on the approximate data, some crude idea will be formed which will be suffice to plan a new stocking exercise. The general aim is to establish a food chain where fish can thrive well without much external feeding and naturally propagate to establish a breeding population. Special emphasis on stocking of Cyprinid species, prawn, *Macrobrachium lancestri* and other invertebates is to be given. The reason is that they form the food of many carnivorous and omnivorous fish species. Care is to be taken so that sampling exercise does not cause problems to ambient water quality, wetland plants and fish stocks. Once established few carp species can be released into main lake and wetlands.

5.3.3 Stocking of Endangered and Rare Species

Stocking of endangered and rare species can be one of the important stocking programmes because the wetland’s unique feature and ecological characteristics. The potential species are *Oxyleotris marmoratus*, *Leptobarbus hoevenii*, *Probarbus jullieni* and *Tor tambroides* and *Osphronemus goramy* and *Scalophagus formosus*.

5.3.4 Illegal Fishing

5.3.4.1 Illegal fishing will be difficult to stop once the wetland system is established when a variety of fish species occupy the productive habitat. Prohibition of illegal fishing can be done by enacting new laws and legislation.

5.3.4.2 In summary, the fish community need to be managed through a fish management plan and the following factors need to be considered.

- Routine sampling to determine the adaptability and recruitment of fish stocked into the wetland system. Evaluate the rate of establishment of fish species to support successful sport and recreational fishery;

- Design restocking plan based on the periodic fish sampling exercise. The type of fish and its stocking density must focus on eliminating undesirable fish species, eg. exotic Tilapia sp. and mosquito larvae;

- Ensure water level optimum for all types of fish to move throughout the water column;

- Enact legislation to protect fish from illegal and destructive catch;

- Promote educational and environmental awareness to protect and promote fish, which are rare and endangered;

- Long-term management and monitoring of fish health and their performance to control water quality control, support sport and recreational fishery and reduce mosquito larvae and other noxious materials in water.

5.4 Birds

5.4.1 The presence of birds need to be monitored to ensure that their presence does not unduly affect the wetlands system and lake water quality. The following actions and factors need to be considered:

- Enact legislation to protect bird from illegal hunting;

- Promote educational and environmental awareness to conserve protected birds;

- Develop an outline plan to for management of the wetland and swamp system for use by resident and migratory birds;

- Catchment management committee to met every month to review the effectiveness of measures undertaken to enhance colonization of birds;

- Identify and declare “unique” any areas inhabited by uncommon birds.

5.4.2 Once the wetland plants and its associated swamp forest are well-established, a diversity of terrestrial and water birds will colonize the habitat. A variety of resident and migratory birds are commonly expected to colonize the habitat. To encourage this, the following steps can be taken:

1. Monitoring of birds during the period of migration to assess population impact;
2. Establishment of sheltered sites for for birds to graze, perch and roost.

Floating rafts anchored to the bottom for example, can provide nesting and protection from disturbance.

5.4.3 The impact of the birds also need to be monitored to ensure the population numbers and type of birds do not compromise water quality.

5.4.4 Community awareness and education programme can be undertaken amongst local residents, school and university students and community leaders and other interested groups to encourage public participation in bird watch and their conservation. A warden service needs to be established to provide public liaison and education on water bird watching.

5.5 Wildlife

5.5.1 Undisturbed forest cover will encourage animal (wildlife) colonization. Once the vegetation cover of the riparian park (swamp strip) of the wetland is established, wildlife colonization will be widely expected.

5.5.2 Similar to the concern for bird life in the wetlands and Lake, wildlife also need to be monitored:

- Enact legislation to protect wildlife from poaching and hunting.

- Promote educational and environmental awareness to conserve wildlife, which are either protected or endangered.

6.0 COMMUNITY AWARENESS AND EDUCATION

Apart from the bio-chemical and other physical controls, community awareness and education amongst common people to appreciate wetlands and its associated plants and fauna are important in promoting their conservation and management. In this respect the NIC in Putrajaya can play an important role in disseminating information.

APPENDIX D

PUTRAJAYA LAKE CATCHMENT

GUIDELINES FOR DEVELOPMENT OF RIPARIAN

MANAGEMENT ZONES (RMZ)

APPENDIX D

PUTRAJAYA LAKE CATCHMENT
GUIDELINES FOR DEVELOPMENT OF RIPARIAN MANAGEMENT ZONES (RMZ)

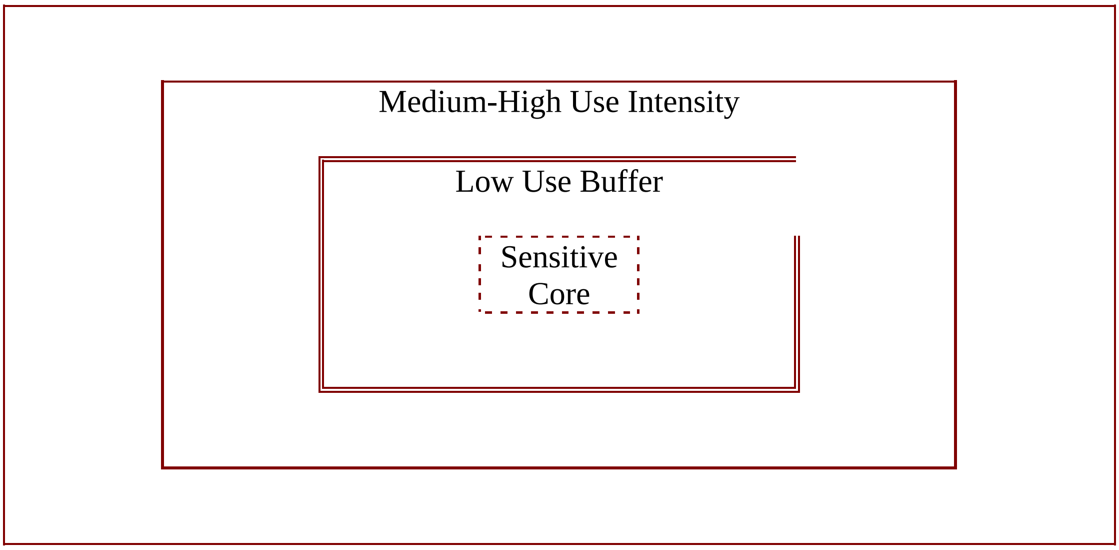
1.0 PURPOSE OF GUIDE

The purpose of this guide to assist in the design of buffers or Riparian Management Zones along drainage lines and water bodies in the Putrajaya Lake Catchment.

2.0 CORE ZONE CONCEPT

In land use design, the identification of sensitive areas may be based on the use of zones. In conservation practice, the ”core zone” principle is used in developing management plans. The central core of a management area is normally considered most sensitive and is most protected from development. This is fringed by a intermediate buffer zone of low intensity use, with increasing intensity use located in the outer fringe to the central core (Figure D.1).

Figure D.1 Core Zone Concept in Conservation



3.0 RIPARIAN MANAGEMENT ZONE CONCEPT

3.1 Within the catchment, the wetlands and natural streams may be considered the most sensitive.

3.2 Management of non-point pollutant input into waters is normally carried out by different management practices based on observations, experimentation and experience. Generally the best management practices for pollutant reduction tries to mimic the natural environment which has been disturbed by man. Thus the more natural-looking an environment the less likely is the pollutant input that might be expected.

3.3 Based on such premise, therefore, there should be as much an abundance of vegetation as possible without it being detrimental to human activities. Within the Putrajaya Lake Catchment the best example of this enforced 'naturalness' is the Sungai Kyok sub-catchment in MARDI. Here the streams and ponds are lined with tall grassess and trees. What might be regarded as an overgrowth of grasses in the streams actually serve multiple functions.

3.4 They

1. increase channel, reduce flow velocity, and carrying erosive or load carrying capacity;
2. trap particulates, and encourage sedimentation;
3. reduce sunlight penetration in the water column, discouraging algal growth, even in excess of nutrients;
4. uptake nutrients in the water column and store in plant materials;
5. provide stable habitats for aquatic ecological systems.

3.5 The development of the Putrajaya Cacthment area therefore should try to simulate such stream or riparian environments along the natural water courses, ponds and even storm drains. Riparian Management Zones (RMZ) should be established following the practice in forestry management.

3.6 Therefore,

1. low use buffer zones comprising riparian management zones or buffer strips (see below) of 30 to 10 m width on each side should be maintained;

2. higher intensity development should be located further away from the water courses.

4.0 RIPARIAN MANAGEMENT ZONE DESIGN

4.1 Components in the RMZ

4.1.1 Riparian Management Zones comprise of three components:

1. a tree-lined corridor along the stream/pond banks which act to provide shade and reduce water temperatures, provide large organic detritus loads to support aquatic ecological system growth, provide a long-term storage for nutrients taken up by its deep and extensive root system, protect the stream from disturbance;
2. a shrub corridor next to the trees as a transitional zone, to the adjacent grassed edge, to provide habitat for birds and small animals, to provide medium term nutrient uptake storage through its moderate-depth root system, to stabilise the soil structure, to act as barrier to control access to the stream;

3. a grassed edge leading away from the shrubs with tall stands to reduce and regularise overland flow runoff, filter sediments in runoff from reaching the stream, provide rapid uptake of nutrients through its fine and shallow rooting system, provide habitat for very small animals and insects, as well as being the transition to more frequently cut traditional lawns and park landscape.

4.1.2 In addition to land zoning, there must also be monitoring and control of chemical use in the catchment. A Pesticide Register should be instituted in the catchment. The BMPs for fertilizer and pesticide use is given in Appendix A and B.

4.1.3 The guidelines for the buffer zone widths based on land slope is given in Table D.1.

Table D.1 Recommended Total RMZ Widths based on Percent Slope for areas with high potential for ground or soil disturbance. (from www.bloomington.in.us/~mjump/Bmp.htm)

Watershed RMZ Slope Characteristic / **Stram Type**	**0-5%**	**5-10%**	**10-20%**	**20-40%**	**>40%**	**Primary Habitat**
Perennial >40' wide	200'	200'	200'	200'	200'	200'
Perennial 20-40' wide	75'	75'	75'	105'	105-165'	75'
Perennial <20' wide	50'	50'	65'	105'	105-165'	35'
Intermittent	25'	45'	65'	105'	105-165'	-
Sinkholes	25'	45'	65'	105'	105-165'	-
Water Supply Reservoirs	75'	90'	130'	210'	210-300'	75'
Other Lakes & Ponds	35'	45'	65'	105'	105-165'	35'

Note: widths are expressed in feet on each side of the watercourse.

4.1.4 The total width of the buffer strip depends in large part on its major functions and the slope and use of the adjacent land. If the major purpose of the buffer strip is sediment removal from surface runoff, a width of 15 m may be sufficient on slopes of 0-5%. If excess nutrient removal also is an important function, a width of 15-30 m might be necessary depending on the kind and quantity of agricultural chemicals applied and the soil and cultivation system used.

4.1.5 As the slope, intensity of land use, or total area of the land producing non-point pollutants increases, or as soil permeability decreases, a wider buffer is required. Buffer strips of 10-60 m wide are recommended for sediment removal, 5-90 m wide for nutrient removal, 5-100 m wide for species diversity and 15-30 m wide for stream water temperature moderation. Studies on buffer strips indicate that the buffer strip widths could be 20% of the total non-point pollutant area.

4.2 Examples of RMZ design

4.2.1 Multi-Species Riparian Buffer Strip (MSRBS) System

4.2.1.1 The Agroecology Issue Team (AIT) of the Leopold Center for Sustainable Agriculture located in Ames, Iowa, U.S.A. and the Iowa State University Agroforestry Research Team (IStART) have developed multi-species riparian buffer strip (MSRBS) system for application in the Midwestern and Great Plains agroecosystem.

4.2.1.2 From the streambank edge,

the first zone of the MSRBS is 10 m wide and contains 4-5 rows of rapidly growing trees. This provides perennial root systems and long-term nutrient storage close to the stream;

the second zone is 4 m wide and contains 1-2 rows of shrubs. The shrubs add more woody stems near the ground to slow flood flows and provide a more diversified wildlife habitat; and

the third zone is a 7 m wide zone of native, warm-season grasses. The grasses provide the high density of stems needed to dissipate the energy of surface runoff and the deep and dense annual root systems act to increase soil infiltration capacities and provide organic matter for large microbial populations.

4.2.1.3 If the area is barren then fast-growing trees are needed to develop a functioning MSRBS in the shortest possible time. It is especially important that rows 1-3 (the first row is the closest to the streambank edge) in the tree zone (zone 1) include fast-growing, riparian species such as willow (Salix spp) species. If, throughout the year, the rooting zone along the streambank is more than 1.2 m above normal stream flow and soils are well drained, then upland trees and even coniferous trees and shrub species can be planted in rows 4 and 5. The slower growing species will not begin to function as nutrient sinks as quickly as faster growing species but are often considered to be better quality trees.

4.2.1.4 Shrubs are included in the design because their permanent roots help maintain soil stability, their multiple stems help slow flood flows and they add biodiversity and provide wildlife habitat. Many local shrubs can be used and selected based on their desirable wildlife and aesthetic values.

4.2.1.5 The grasses function to intercept and dissipate the energy of surface runoff, trap sediment and agricultural chemicals in the surface runoff, and improve soil quality by increasing infiltration capacity and microbial activity as a result of their annually high turnover of roots. Tall grasses are better suited to the MSRBS than shorter grasses that are usually used for lawns because of their taller and stiffer stems and their more deeply distributed roots. A minimum grass zone width of 7 m is recommended to dissipate the surface runoff, trap sediment, and promote significant infiltration.

4.2.2 Other Systems

4.2.2.1 The three zone MSRBS model of trees, shrubs, and prairie grasses is well suited to the agro-ecosystems of the Midwest and eastern Great Plains. Other combinations of flora types can also be effective. These might include combinations with more trees or shrubs or without any trees or shrubs, except for those used for streambank stabilization.

4.2.2.2 The grass zone is the most critical of the three zones in the MSRBS. Site conditions, major buffer strip biological and physical functions, cost and maintenance requirements need to be considered in specifying species combinations.