# CHAPTER 4

# RESULTS

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## 4.1 Description of the Putrajaya Freshwater Ecosystem

### 4.1.1 Before Wetlands Construction

Before the construction of wetland, the study area was primarily agricultural in nature consisting of oil palm and rubber plantation between twelve to fifteen years old. The land was undulating (predominantly Serdang and Prang Besar Series Soils) (PP and PJH, 1999). Some other shade tolerant species were also found for example, creepers, scramblers and various ferns. There were a few rivers, Sg. Bisa, Sg. Chuau and Sg Limau Manis, which were generally small streams, between two to four metres wide and 0.3 – 1.5 metres deep join to Sg Langat.

There were small mammals, some reptiles, amphibians and resident birds found in the study area before the construction, which were mainly the typical fauna of an oil palm and rubber plantation (PP and PJH, 1999). The list of flora and fauna found before the wetlands are presented in Appendix 2.

### 4.1.2 After Wetlands Construction

During the construction of wetlands, Sg. Chuau and Sg. Bisa were being converted to wetland cells and planted with different type of wetland plants to form a wetlands system. The wetland cells in Putrajaya were completed in year 1999. Each of the wetland cells was planted with different wetlands plants including the shallow marsh, marsh and deep marsh species (Table 7).

After the planting period, a large diverse aquatic plants, trees and bushes lining the littoral zone form a crucial and important part of the "green corridor" of Taman Wetlands of Putrajaya (PP and PJH, 1999). The large diversity of plants and insects provide a broad food base that attracts different birds to enhance the sustainability of the wildlife. The most noticeable changes were the increase in the population of dragonflies and birds such as swifts, moor hens, water hens, wild ducks, kingfishers and some migratory birds. The migratory birds are believed to have come from their traditional feeding grounds – the natural wetlands and abandoned mining ponds in the nearby area (PP and PJH, 1999).

In the wetlands, fishes including those that feed on mosquito larvae such as pelaga *(Beta pugnax)*, sepat siam *(Trichogaster pectoralis)* and *Gambusai affinis* were introduced into the wetland cells in to order achieve a balanced and sustainable aquatic system. In the larger and deeper Central Wetlands and Putrajaya Primary Lake, fishes such as patin *(Pangasius pangasius)*, baung (*Mystus* spp.), tengalan *(Puntius bulu)*, sebarau *(Hampala macrolepidota)* and temoleh *(Probarbus jullieni)* were introduced (PP and PJH, 1999).

The fish stocking aims to:

- Maintain good water quality (physically and biologically)
- Mosquito larvae control
- Provision for sport fishing
- Aesthetic and ornamental value

In the constructed wetlands, different plants indigenous to Peninsular Malaysia were planted. The wetland plants were planted based on the different water depth. The planting zones comprise of the macrophytic, fringing vegetation and swamp forest. Tables 7 – 9 showed the list of species for the three different zones respectively.

**Table 7. Species in the Macrophytic Sub-zones**

| Botanical Name | Common Name |
|---|---|
| **Shallow Marsh (water depth 0 - 0.3 m)** | |
| *Eloeocharis variegata* | puron, spike rush |
| *Eriocaulon longifolium* | rumput butang, Asiatic pipewort |
| *Fimbristylis globulosa* | rumput sadang, globular Fimbristylis |
| *Fimbristylis miliacea* | rumput tahi kerbau, lesser Fimbristylis |
| *Hanguana malayana* | bakong, common Hanguana |
| *Ludwigia adscendens* | inai pasir, water primrose |
| *Ludwigia octovalvis* | naleh, hairy Malayan willow herb |
| *Monochoria hastata* | keladi agas, hastate-leafed pondweed |
| *Philydrum lanuginosum* | rumput kipas, fan grass |
| *Polygonum barbatum* | tebuk seludang, knot grass |
| *Saccharum spontaneum* | tebu salah, swamp sugar cane |
| *Scleria sumatrensis* | rumput sendayan, Sumatran Scleria |
| **Marsh (water depth 0.3 - 0.6 m)** | |
| *Eleocharis dulcis* | ubi puron, spike rush |
| *Fuirena umbellata* | rumput kelulut, hairy blue sedge |
| *Lepironia articulata* | purun, tube sedge |
| *Philydrum lanuginosum* | rumput kipas, fan grass |
| *Scirpus grossus* | rumput menderong, greater club rush |
| *Scirpus mucronatus* | rumput kercut, bog bulrush |

Continue Table 7

| Botanical Name | Common Name |
|---|---|
| *Scleria sumatrensis* | rumput sendayan, Sumatran Scleria |
| *Typha augustifolia* | banat, cat-tail |
| **Deep Marsh (water depth 0.6 - 1.0 m)** | |
| *Lepironia articulata* | purun, tube sedge |
| *Phragmites karka* | rumput gedabong, common reed |
| *Scirpus grossus* | rumput menderong, greater club rush |
| *Scirpus mucronatus* | rumput kercut, bog bulrush |
| *Typha angustifolia* | banat, cat-tail |

## Table 8. Species in the Fringing Marsh (Zone F1 of the ZII)

| Botanical Name | Common Name |
|---|---|
| *Alocasia macrorrhiza* | senteh, elephant's ear |
| *Alstonia spathulata* | pulai paya, marsh pulai |
| *Colocasia gigantea/esculenta* | keladi, coco-yam |
| *Commelina nudiflora* | rumput aur, common spiderwort |
| *Crinum asiaticum* | bakong, sea-shore Crinum |
| *Dillenia suffritcosa* | simpoh air, shrubby simpoh |
| *Cyperus halpan* | rumput sumbu, sheathed Cyperus |
| *Cyperus compactus* | para-para, swamp Mariscus |
| *Cyperus digitatus* | rumput bunga satuan, digitate Cyperus |
| *Eleocharis variegata* | puron, spike rush |
| *Eugenia longifolia* | common kelat |
| *Eriocaulon longifolium* | rumput butang, Asiatic pipewort |
| *Fimbristylis miliacea* | rumput tahi kerbau, lesser Fimbristylis |
| *Ludwigia octovalvis* | naleh, hairy Malayan willow herb |
| *Pandanus immersus* | rasau, riverine Pandanus |
| *Ploiarium alternifolium* | riang-riang, cicada tree |
| *Polygonum barbatum* | tebuk seludang, knot grass |
| *Rhynchospora corymbosa* | rumput sendayan, golden beak sedge |
| *Saraca thaipingiensis* | gapis |
| *Scirpus juncoides* | rumput bulat, upright club rush |

**Table 9. Species in the Swamp Forest (Zone F2 of the ZII)**

| Botanical Name | Common Name |
|---|---|
| *Alstonia spathulata* | pulai paya, marsh pulai |
| *Artocarpus heterophyllus* | nangka, jack-fruit |
| *Arundina graminifolia* | Tapah weed |
| *Caryota mitis* | rabok, fish-tail palm |
| *Centella asiatica* | pegaga, Indian pennywort |
| *Commelina nudiflora* | rumput aur, common spiderwort |
| *Cerbera odollam* | pong-pong, yellow-eyed Cerbera |
| *Cratoxylon arborescens* | geronggong |
| *Cyrtostachys renda* | pinang raja, sealing-wax palm |
| *Dillenia suffruticosa* | simpoh air, shrubby simpoh |
| *Elaeocarpus nitidus* | jiremong, walnut oil fruit |
| *Eugenia aquea* | jambu air, wax apple |
| *Eugenia longifolia* | common kelat |
| *Fagraea fagrans* | tembusu, |
| *Ficus benjamina* | waringin |
| *Ficus microcarpa* | jejawi, Malayan banyan |
| *Flagellaria indica* | rotan tikus, common Flagellaria |
| *Garcinia mangostana* | mangis, mangosteen |
| *Hibiscus tiliaceus* | baru-baru, sea hibiscus |
| *Ixora javanica* | Javanese Ixora |
| *Ixora umbellata* | Malayan white Ixora |
| *Koompassia malaccensis* | kempas |
| *Lansium domesticum* | langsat |
| *Licuala spinosa* | palas |
| *Litsea teysmanni* | medang kelor |
| *Melaleuca cajuputi* | gelam, paper-bark tree |
| *Nepenthes gracilis* | periok kera, slender pitcher plant |
| *Pometia pinnata* | kasai |
| *Santiria rubiginosa* | kerantai |
| *Saraca thaipingiensis* | gapis |
| *Shorea parvifolia* | meranti sarang punai |

## 4.2 Baseline Information on River Water Quality

Generally, Sg. Chuau was first monitored by the DOE in 1995. The water quality was classified as clean river with a WQI of 84 (DOE, 1995). In December 1996, the water quality at Putrajaya was monitored before the construction of wetlands and the water quality index ranged between 81.3 to 91.5. These values indicated that the water was still clean. Table 10 shows the water quality index obtained from the monitoring station work from the proposed Putrajaya Wetlands and Lake Development.

**Table 10. Water Quality Index of Water in the Putrajaya Wetlands, 9-11th December 1996**

| Sample | Description of the water quality stations | Water Quality Index (WQI) |
|---|---|---|
| 1 | Sg Chuau NE tributary | 81.3 |
| 2 | Inlet to Upper North (UN) | 88.5 |
| 3 | Secondary Lake Weir (Central Lake) | 91.5 |
| 4 | Temporary Dam Primary Lake | 89.7 |

## 4.3 Trend in Water Quality Index (WQI)

WQI was obtained from Upper North Wetland (UN), Central Wetland (CW) and Primary Lake (PL). Five parameters – pH, DO, BOD, COD, TSS and AN were put into an equation to derive overall WQI for the sample. All the data presented will be arranged according to the three phases; Pre-construction period (March 1997 – April 1998), during construction/planting period (May 1998 – September 1999) and after construction/maintenance period (October 1999 – July 2000). Water Quality Index for the three different phases and different wetland cells are presented in Tables 11 – 13. These tables show the minimum and maximum with their mean and standard deviation for each sampling occasion for each site. As for the trend of WQI, it is shown in Figure 9-10 with lines drawn at WQI 60 and WQI 80. The lines demarcate the boundaries between polluted and slightly polluted water (WQI 60) and between slightly polluted and clean water (WQI 80).

### 4.3.1 Pre-construction of Wetland Cells

During the pre-construction of wetland cells, WQI for UN, CW and PL ranged from 52.2 to 86.8, 65.3 to 88.7 and 55.6 to 86.5 respectively (Figure 40). In UN, the minimum WQI was recorded in August 1997 and maximum in April 1997 (Table 11). The mean WQI for UN was 74.7 ± 4.2. In CW, the minimum WQI of obtained in the month of June 1997 and for PL, the minimum was obtained in the month of August 1997. The maximum WQI for CW and PL was obtained in the month of April 1997 and February 1998 respectively. However, during this phase, the mean WQI for CW and PL was in the range for slightly polluted condition which was 76.4 ± 2.2 and 73.3 ± 2.9 respectively.

### 4.3.2 During Construction of Wetland Cells

The mean WQI was 86.1 ± 2.8, 86.4 ± 1.6 and 84.1 ± 1.8 for UN, CW and PL respectively. WQI ranged from 75.0 to 93.2, 76.4 to 92.9 and 67.1 to 92.3 for UN, CW and PL respectively (Figure 41). The minimum WQI for UN and CW was recorded in the month of June 1998. The minimum WQI for PL was recorded in September 1998. The maximum WQI was recorded in January 1999 for UN, September 1999 for CW and PL (Table 12).

### 4.3.3 After Construction of Wetland Cells

After the construction of wetland cells, WQI for UN, CW and PL ranged from 73.0 to 92.0, 82.0 to 93.2 and 76.0 to 98.5 respectively (Figure 42). The mean WQI for this period for the three sites was above 80, which is classified as clean. The mean WQI for UN, CW and PL recorded was $84.3 \pm 3.1$, $87.8 \pm 2.3$ and $88.6 \pm 2.8$ respectively. However, the minimum WQI was recorded in January 2002 for UN and April 2002 for PL with WQI below 80 (Table 13).

Figure 40 shows the trend of mean water quality indices for UN, CW and PL for pre-construction of wetland cells. Based on the graph, the trend of WQI for pre-construction and during construction of wetland cells (Figures 40 and 41) was within the range of slightly polluted with WQI range from 59.0 – 80.0. However, after construction of wetland cells, the WQI was in the range of clean water with WQI above 79.0 (Figure 42).

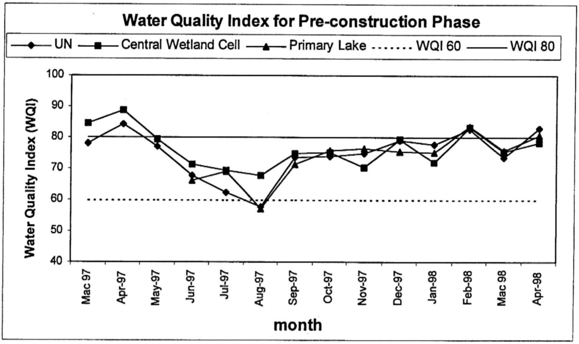


**Figure 40. WQI for Pre-construction of Wetland Cells for UN, CW and PL**

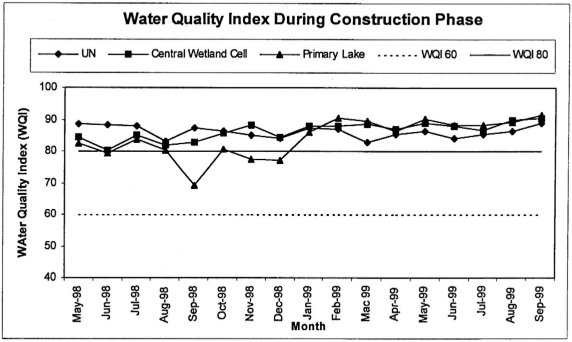


**Figure 41. WQI During Construction of Wetland Cells for UN, CW and PL**

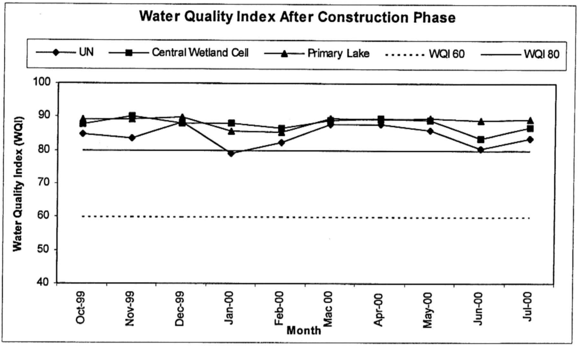


**Figure 42. WQI After Construction of wetland cells for UN, CW and PL**

**construction of Wetland Cells**

| Months | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| Mac '97 | 68.7 | 82.5 | 78.2 (6.4) | 83.4 | 85.8 | 84.6 (1.7) | N/A | N/A | N/A |
| Apr '97 | 83.1 | 86.8 | 84.3 (1.7) | 88.6 | 88.7 | 88.7 (0.1) | N/A | N/A | N/A |
| May '97 | 69.2 | 83.3 | 77.1 (5.8) | 79.1 | 79.8 | 79.4 (0.5) | N/A | N/A | N/A |
| June '97 | 57.7 | 71.9 | 67.9 (6.8) | 65.3 | 77.5 | 71.4 (8.7) | 58.0 | 74.3 | 66.2 (8.1) |
| July '97 | 54.0 | 67.8 | 62.3 (6.0) | 67.3 | 71.8 | 69.5 (3.1) | 67.0 | 71.0 | 68.9 (2.0) |
| Aug '97 | 52.2 | 62.1 | 57.7 (5.0) | 67.9 | 68.0 | 67.9 (0.1) | 55.6 | 60.6 | 57.2 (2.9) |
| Sep '97 | 71.9 | 75.7 | 73.5 (1.6) | 73.0 | 76.7 | 74.8 (2.6) | 70.4 | 72.7 | 71.4 (1.1) |
| Oct '97 | 70.3 | 83.8 | 74.0 (6.5) | 74.8 | 75.3 | 75.1 (0.4) | 73.7 | 78.1 | 75.8 (2.2) |
| Nov '97 | 70.9 | 78.5 | 74.7 (3.4) | 66.9 | 73.8 | 70.3 (4.9) | 75.6 | 77.3 | 76.3 (0.9) |
| Dec '97 | 75.8 | 82.2 | 78.9 (2.7) | 78.3 | 80.1 | 79.2 (1.2) | 72.5 | 79.1 | 75.6 (3.3) |
| Jan '98 | 72.7 | 80.5 | 77.6 (3.7) | 70.8 | 72.9 | 71.8 (1.5) | 69.7 | 78.7 | 75.2 (4.8) |
| Feb '98 | 81.2 | 84.9 | 82.7 (1.7) | 81.6 | 85.0 | 83.3 (2.4) | 81.0 | 86.5 | 83.4 (2.8) |
| Mac '98 | 70.2 | 79.8 | 73.4 (4.3) | 75.2 | 76.0 | 75.6 (0.6) | 73.3 | 78.2 | 75.8 (2.5) |
| Apr '98 | 77.8 | 86.5 | 82.8 (3.8) | 76.8 | 80.3 | 78.5 (2.5) | 80.0 | 81.3 | 80.8 (0.7) |
| Mean | | | 74.7 (4.2) | | | 76.4 (2.2) | | | 73.3 (2.9) |

Note: N/A = Not available

| Months | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| May '98 | 85.5 | 90.2 | 88.5 (1.7) | 82.9 | 85.7 | 84.3 (2.0) | 81.4 | 84.6 | 82.6 (1.8) |
| June '98 | 82.8 | 91.7 | 88.1 (3.4) | 76.4 | 84.2 | 80.3 (5.5) | 76.2 | 83.6 | 79.3 (3.8) |
| July '98 | 83.6 | 90.8 | 87.8 (2.6) | 84.9 | 85.5 | 85.2 (0.4) | 82.9 | 85.0 | 83.9 (1.0) |
| Aug '98 | 77.1 | 86.3 | 83.2 (3.5) | 79.9 | 83.8 | 81.8 (2.8) | 78.9 | 82.5 | 80.2 (2.0) |
| Sep '98 | 83.3 | 89.8 | 87.4 (2.6) | 80.1 | 85.5 | 82.8 (3.8) | 67.1 | 71.9 | 69.1 (2.5) |
| Oct '98 | 82.2 | 90.3 | 86.5 (2.9) | 85.0 | 86.7 | 85.8 (1.2) | 77.4 | 84.2 | 80.7 (3.4) |
| Nov '98 | 82.5 | 88.6 | 85.2 (2.0) | 88.1 | 88.3 | 88.2 (0.2) | 76.9 | 77.7 | 77.4 (0.4) |
| Dec '98 | 75.9 | 88.3 | 84.2 (3.9) | 83.5 | 85.1 | 84.3 (1.1) | 72.5 | 79.2 | 77.0 (3.9) |
| Jan '99 | 84.1 | 93.2 | 87.4 (3.1) | 87.0 | 88.7 | 87.8 (1.2) | 85.1 | 86.6 | 86.1 (0.9) |
| Feb '99 | 83.2 | 88.7 | 86.9 (1.9) | 86.2 | 89.7 | 87.9 (1.9) | 87.1 | 92.2 | 90.5 (2.3) |
| Mac '99 | 78.2 | 87.4 | 82.7 (3.2) | 87.5 | 90.0 | 88.7 (1.1) | 88.9 | 90.1 | 89.4 (0.5) |
| Apr '99 | 82.44 | 88.7 | 85.4 (2.2) | 86.8 | 87.7 | 87.1 (0.4) | 82.6 | 88.9 | 86.5 (2.7) |
| May '99 | 83.6 | 87.6 | 86.2 (1.4) | 86.9 | 89.9 | 89.0 (1.4) | 87.8 | 92.2 | 90.1 (2.0) |
| June '99 | 75.0 | 88.5 | 84.2 (4.2) | 87.0 | 88.9 | 87.9 (0.9) | 87.0 | 89.5 | 88.3 (1.0) |
| July '99 | 81.7 | 87.0 | 85.3 (1.6) | 86.0 | 87.9 | 86.8 (0.8) | 87.2 | 89.4 | 88.3 (1.0) |

*Continue Table 12*

| Months | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| Aug '99 | 83.0 | 88.7 | 86.3 (2.1) | 88.8 | 91.3 | 90.0 (1.4) | 88.6 | 90.0 | 89.3 (0.6) |
| Sep '99 | 79.6 | 93.1 | 88.9 (4.6) | 89.3 | 92.9 | 90.4 (1.6) | 90.9 | 92.3 | 91.3 (0.6) |
| Mean | | | 86.1 (2.8) | | | 86.4 (1.6) | | | 84.1 (1.8) |

| Months | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| Oct '99 | 78.3 | 88.0 | 84.7 (3.1) | 86.1 | 89.1 | 87.8 (1.5) | 87.6 | 90.3 | 89.3 (1.2) |
| Nov '99 | 80.5 | 85.9 | 83.5 (1.8) | 89.4 | 91.0 | 90.0 (0.7) | 88.3 | 90.7 | 89.3 (1.1) |
| Dec '99 | 82.7 | 92.0 | 88.3 (2.8) | 82.2 | 93.2 | 88.1 (4.9) | 77.0 | 94.6 | 89.9 (4.8) |
| Jan '00 | 73.0 | 82.8 | 79.1 (3.0) | 85.4 | 90.4 | 88.0 (2.4) | 82.4 | 88.8 | 85.5 (2.5) |
| Feb '00 | 74.8 | 87.2 | 82.4 (4.0) | 82.8 | 87.9 | 86.4 (2.4) | 79.7 | 86.8 | 85.2 (2.3) |
| Mac '00 | 84.5 | 91.4 | 87.7 (2.3) | 84.9 | 91.9 | 89.0 (3.0) | 82.6 | 91.7 | 89.6 (2.6) |
| Apr '00 | 84.0 | 90.9 | 87.8 (2.2) | 86.4 | 90.7 | 89.5 (2.1) | 76.0 | 92.7 | 89.1 (4.9) |
| May '00 | 82.0 | 88.3 | 85.8 (1.9) | 87.5 | 90.7 | 89.0 (1.3) | 83.0 | 98.5 | 89.6 (4.1) |
| June '00 | 76.2 | 84.4 | 80.5 (3.0) | 82.0 | 84.2 | 83.5 (1.0) | 84.5 | 92.6 | 88.9 (3.0) |
| July '00 | 68.0 | 88.7 | 83.6 (6.5) | 83.0 | 90.0 | 86.8 (3.3) | 85.7 | 91.8 | 89.1 (1.8) |
| Mean | | | 84.3 (3.1) | | | 87.8 (2.3) | | | 88.6 (2.8) |

## 4.4 Trend of Water Quality Parameters

Water quality parameters included pH, DO, BOD, COD, AN and TSS for each wetland cells were recorded and analysed. Each of the water quality parameters will be presented with different phase for each wetland cells. Tables and figures below show the minimum, maximum values with their mean and standard deviation of each of the water quality parameters for each wetland cells at different phases. All the data presented start from the month of March 1997 and end in July 2002 except for PL. Water quality sampling for PL was carried out in June 1997 only.

### 4.4.1 Water Quality Parameters for Pre-construction of Wetland Cells

#### 4.4.1.1 pH

The pH for pre-construction of wetland cells for UN, CW and PL ranged from 6.4 – 8.6, 6.3 to 8.2, 6.0 to 9.0. The mean pH for UN, CW and PL recorded was 7.4 ± 0.2, 7.2 ± 0.1, 7.3 ± 0.4 respectively (Table 14). The minimum pH for UN, CW and PL was recorded in August 1997, June 1997 and November 1997 and the maximum pH for UN and CW was recorded in October 1997. For PL, the maximum pH was recorded in September 1997.

Based on the graph (Figure 43), it is obvious that there was a peak of the mean pH during the month of September 1997 and October 1997 recorded for UN, CW and PL. The mean pH then decreased and fluctuated up again in the month of April 98.

**Table 14. pH Values for Pre-construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| Mac '97 | 6.5 | 6.8 | 6.6 (0.1) | 6.4 | 6.7 | 6.6 (0.2) | N/A | N/A | N/A |
| Apr '97 | 6.8 | 7.0 | 6.9 (0.1) | 6.4 | 6.8 | 6.6 (0.3) | N/A | N/A | N/A |
| May '97 | 6.6 | 6.9 | 6.8 (0.1) | 6.5 | 6.6 | 6.6 (0.1) | N/A | N/A | N/A |
| June '97 | 6.6 | 7.0 | 6.8 (0.2) | 6.3 | 7.0 | 6.7 (0.5) | 6.6 | 6.8 | 6.7 (0.1) |
| July '97 | 6.4 | 7.0 | 6.8 (0.3) | 6.4 | 6.7 | 6.6 (0.2) | 6.5 | 6.9 | 6.7 (0.2) |
| Aug '97 | 6.4 | 7.1 | 6.9 (0.3) | 6.7 | 7.0 | 6.9 (0.2) | 6.5 | 6.8 | 6.7 (0.2) |
| Sep '97 | 8 | 8.4 | 8.3 (0.2) | 8.2 | 8.2 | 8.2 (0.0) | 8.4 | 9.0 | 8.7 (0.3) |
| Oct '97 | 7.0 | 8.6 | 7.9 (0.7) | 8.1 | 8.2 | 8.2 (0.1) | 6.1 | 8.1 | 7.4 (1.2) |
| Nov '97 | 6.8 | 7.0 | 6.9 (0.1) | 6.6 | 6.7 | 6.7 (0.1) | 6.0 | 6.7 | 6.3 (0.4) |
| Dec '97 | 7.3 | 7.5 | 7.4 (0.1) | 7.3 | 7.3 | 7.3 (0.0) | 6.3 | 7.2 | 6.8 (0.5) |
| Jan '98 | 7.7 | 8.2 | 8.0 (0.2) | 7.8 | 7.6 | 7.7 (0.1) | 7.4 | 7.9 | 7.6 (0.3) |
| Feb '98 | 7.6 | 8.2 | 8.0 (0.3 | 8.0 | 8.0 | 8.0 (0.0) | 7.7 | 8.1 | 7.9 (0.2) |
| Mac '98 | 7.7 | 7.8 | 7.7 (0.1) | 7.8 | 7.5 | 7.7 (0.2) | 6.6 | 7.5 | 7.1 (0.5) |
| Apr '98 | 7.9 | 8.5 | 8.3 (0.3) | 7.6 | 7.6 | 7.6 (0.0) | 7.6 | 8.1 | 7.9 (0.3) |
| Mean | | | 7.4 (0.2) | | | 7.2 (0.1) | | | 7.3 (0.4) |

Note: N/A = Not available

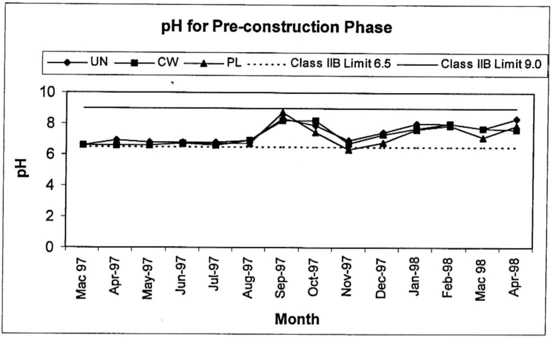


**Figure 43. pH Values for Pre-construction of Wetland Cells**

4.4.1.2 Dissolved Oxygen (DO)

Table 15 shows the DO values for UN, CW and PL ranged from 1.9 to 7.5 mg $L^{-1}$, 3.7 to 7.6 mg $L^{-1}$ and 3.8 to 7.5 mg $L^{-1}$. The mean DO recorded was $5.7 \pm 0.5$ mg $L^{-1}$, $6.1 \pm 0.3$ mg $L^{-1}$ and $5.9 \pm 0.4$ mg $L^{-1}$ for UN, CW and PL respectively. The minimum DO was recorded in August 1997 for UN and CW. For PL, the minimum DO was recorded in June 1997. The highest DO was recorded in April 1998, January 1998 and March 1998 for UN, CW and PL.

Figure 44 shows the trends of DO at UN, CW and PL respectively. At the beginning of the phase, the DO ranged between 5 – 7 mg $L^{-1}$. The DO decreased and reached the lowest level in August 1997 for the three sites. The DO values increased after the month of August 1997.

**Table 15. DO Values (mg $L^{-1}$) for Pre-construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| Mac '97 | 4.7 | 5.7 | 5.3 (0.4) | 5.2 | 5.6 | 5.4 (0.3) | N/A | N/A | N/A |
| Apr '97 | 4.7 | 5.8 | 5.0 (0.6) | 6.2 | 6.7 | 6.5 (0.4) | N/A | N/A | N/A |
| May '97 | 4.2 | 5.2 | 4.7 (0.4) | 5.1 | 5.7 | 5.4 (0.4) | N/A | N/A | N/A |
| June '97 | 4.3 | 6.0 | 5.3 (0.8) | 5.5 | 6.0 | 5.8 (0.4) | 3.8 | 4.7 | 4.3 (0.5) |
| July '97 | 3.3 | 4.1 | 3.7 (0.3) | 4.2 | 5.5 | 4.9 (0.9) | 4.3 | 5.0 | 4.5 (0.4) |
| Aug '97 | 1.9 | 3.8 | 2.9 (0.8) | 3.7 | 4.1 | 3.9 (0.3) | 4.0 | 4.8 | 4.4 (0.4) |
| Sep '97 | 5.0 | 6.9 | 6.2 (0.8) | 5.8 | 6.2 | 6.0 (0.3) | 5.9 | 6.7 | 6.2 (0.4) |
| Oct '97 | 5.9 | 6.5 | 6.2 (0.2) | 6.0 | 6.1 | 6.1 (0.1) | 5.7 | 6.3 | 6.1 (0.3) |
| Nov '97 | 6.0 | 6.9 | 6.5 (0.4) | 6.3 | 6.4 | 6.4 (0.1) | 5.8 | 6.7 | 6.1 (0.5) |
| Dec '97 | 6.7 | 7.2 | 6.9 (0.3) | 6.7 | 6.9 | 6.8 (0.1) | 6.2 | 6.6 | 6.5 (0.2) |
| Jan '98 | 6.7 | 7.2 | 7.0 (0.3) | 7.4 | 7.6 | 7.5 (0.1) | 5.7 | 6.9 | 6.4 (0.6) |
| Feb '98 | 6.0 | 7.3 | 6.6 (0.7) | 6.7 | 7.0 | 6.9 (0.2) | 5.9 | 7.3 | 6.7 (0.7) |
| Mac '98 | 6.3 | 7.3 | 6.8 (0.4) | 6.5 | 6.7 | 6.6 (0.1) | 7.0 | 7.5 | 7.3 (0.3) |
| Apr '98 | 6.6 | 7.5 | 6.9 (0.4) | 6.7 | 6.7 | 6.7 (0.0) | 6.2 | 7.3 | 6.7 (0.6) |
| Mean | | | 5.7 (0.5) | | | 6.1 (0.3) | | | 5.9 (0.4) |

Note: N/A = Not available

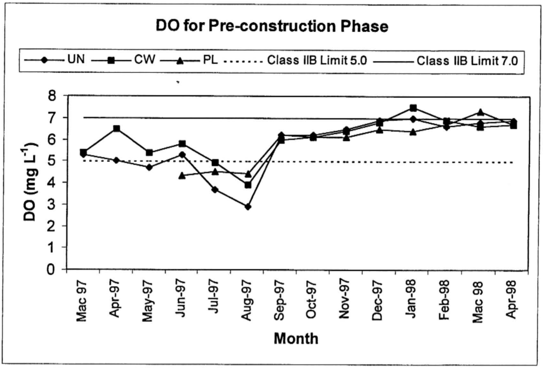


**Figure 44. DO Values (mg $L^{-1}$) for Pre-construction of Wetland Cells**

4.4.1.3 Biochemical Oxygen Demand (BOD)

The BOD values for pre-construction of wetland cells for UN, CW and PL ranged from 0.5 – 16.3 mg $L^{-1}$, 1.2 to 12.5 mg $L^{-1}$, 0.2 to 38.5 mg $L^{-1}$ respectively. The mean BOD for UN, CW and PL recorded was 4.4 ± 1.8 mg $L^{-1}$, 3.8 ± 1.3 mg $L^{-1}$, 4.8 ± 24 mg $L^{-1}$ respectively (Table 16). The minimum BOD for UN and CW was recorded in April 1997. For PL, the minimum BOD was recorded in December 1997. The maximum BOD was recorded in March 1997, January 1998 and August 1997 for UN, CW and PL.

Based on the graph (Figure 45), it is obvious that there is a peak of the mean BOD during the month of August 1997 recorded for UN and PL. This is followed by January 1998 for CW.

**Table 16. BOD Values (mg $L^{-1}$) for Pre-construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| Mac '97 | 2.2 | 16.3 | 6.7 (6.5) | 1.3 | 1.6 | 1.5 (0.2) | N/A | N/A | N/A |
| Apr '97 | 0.5 | 0.9 | 0.7 (0.2) | 0.9 | 1.0 | 1.0 (0.1) | N/A | N/A | N/A |
| May '97 | 1.6 | 8.3 | 3.8 (3.1) | 2.3 | 3.7 | 3.0 (1.0) | N/A | N/A | N/A |
| June '97 | 4.5 | 9.1 | 6.0 (2.1) | 4.5 | 5.9 | 5.2 (1.0) | 2.5 | 7.6 | 5.1 (2.6) |
| July '97 | 5.4 | 10.9 | 7.9 (2.5) | 1.5 | 3.7 | 2.6 (1.6) | 4.5 | 5.8 | 5.0 (0.7) |
| Aug '97 | 5.8 | 10.3 | 8.2 (1.9) | 3.5 | 5.9 | 4.7 (1.7) | 3.8 | 24.8 | 13.0 (10.8) |
| Sep '97 | 1.3 | 3.9 | 2.9 (1.1) | 1.9 | 2.6 | 2.3 (0.5) | 2.7 | 3.6 | 3.0 (0.5) |
| Oct '97 | 4.4 | 6.3 | 5.5 (0.8) | 3.5 | 5.1 | 4.3 (1.1) | 2.6 | 6.3 | 4.6 (1.9) |
| Nov '97 | 3.9 | 5.9 | 4.7 (1.0) | 3.7 | 11.3 | 7.5 (5.4) | 3.6 | 5.6 | 4.7 (1.0) |
| Dec '97 | 1.2 | 2.7 | 1.9 (0.7) | 1.2 | 2.9 | 2.1 (1.2) | 0.2 | 5.9 | 3.4 (2.9) |
| Jan '98 | 4.1 | 12.2 | 6.7 (3.8) | 10.5 | 12.5 | 11.5 (1.4) | 4.3 | 13.5 | 7.7 (5.1) |
| Feb '98 | 1.5 | 2.1 | 1.9 (0.3) | 1.5 | 1.7 | 1.5 (1.6) | 1.2 | 1.8 | 1.5 (0.3) |
| Mac '98 | 2.0 | 3.2 | 2.3 (0.6) | 2.0 | 2.5 | 2.3 (0.4) | 2.0 | 3.2 | 2.5 (0.6) |
| Apr '98 | 2.0 | 4.0 | 2.5 (1.0) | 2.5 | 3.5 | 3.0 (0.7) | 2.0 | 2.0 | 2.0 (0.0) |
| Mean | | | 4.4 (1.8) | | | 3.8 (1.3) | | | 4.8 (2.4) |

Note: N/A = Not available

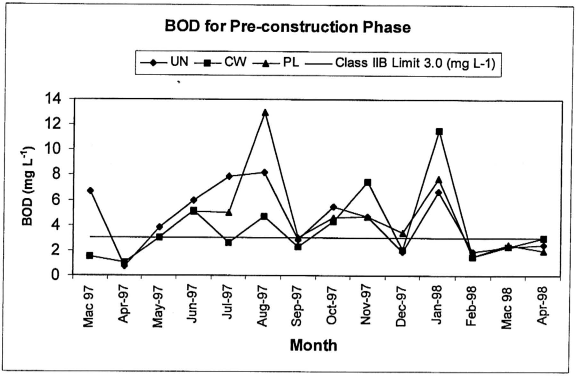


**Figure 45. BOD Values (mg L$^{-1}$) for Pre-construction of Wetland Cells**

4.4.1.4 Chemical Oxygen Demand (COD)

The mean COD values for pre-construction of wetland cells as shown in Table 17 were 11.7 ± 5.6 mg L$^{-1}$ for UN, 10.8 ± 2.7 mg L$^{-1}$ for CW and 13.8 ± 7.2 f mg L$^{-1}$ or PL. COD ranged from 1.0 to 53.0 mg L$^{-1}$ for UN, 1.0 to 32.5 mg L$^{-1}$ for CW and 1.0 to 38.5 for PL with minimum COD recorded in April and September 1997, April 1997 and December 1997 for UN, CW and PL respectively. The maximum COD for the three sites were recorded in March 1997 for UN, June 1997 for CW and August 1997 for PL. Figure 46 shows the mean COD trend in UN, CW and PL. Based on the graph, it is obvious that the mean COD ranged within the Class IIB limit of 25 mg L$^{-1}$ except for the mean COD recorded for PL in June and August 1997.

**Table 17. COD Values (mg $L^{-1}$) for Pre-construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| Mac '97 | 6.5 | 53.0 | 18.5 (23.0) | 6.0 | 8.5 | 7.3 (1.8) | N/A | N/A | N/A |
| Apr '97 | 1.0 | 1.0 | 1.0 (0.0) | 1.0 | 1.0 | 1.0 (0.0) | N/A | N/A | N/A |
| May '97 | 9.5 | 26.5 | 14.5 (8.1) | 8.0 | 12.0 | 10.0 (2.8) | N/A | N/A | N/A |
| June '97 | 14.0 | 30.0 | 20.1 (7.4) | 15.0 | 32.5 | 23.8 (12.4) | 9.0 | 69.0 | 39.0 (30.0) |
| July '97 | 11.5 | 29.5 | 18.6 (7.7) | 12.5 | 13.0 | 12.8 (0.4) | 12.5 | 17.0 | 14.5 (2.3) |
| Aug '97 | 14.5 | 30.5 | 21.9 (6.9) | 11.5 | 14.0 | 12.8 (1.8) | 13.5 | 38.5 | 26.8 (12.6) |
| Sep '97 | 1.0 | 8.5 | 5.8 (3.3) | 4.0 | 4.5 | 4.3 (0.4) | 5.0 | 8.5 | 7.0 (1.8) |
| Oct '97 | 9.5 | 16.5 | 13.5 (3.3) | 13.5 | 18.0 | 15.8 (3.2) | 8.0 | 17.5 | 13.2 (4.8) |
| Nov '97 | 9.0 | 13.5 | 11.3 (2.1) | 15.5 | 23.0 | 19.3 (5.3) | 6.7 | 12.0 | 9.7 (2.7) |
| Dec '97 | 2.0 | 6.0 | 3.5 (1.9) | 2.0 | 3.5 | 2.8 (1.1) | 1.0 | 18.0 | 7.0 (9.5) |
| Jan '98 | 9.0 | 22.5 | 12.6 (6.6) | 18.0 | 23.5 | 20.8 (3.9) | 10.0 | 23.5 | 14.7 (7.7) |
| Feb '98 | 2.0 | 6.5 | 4.3 (1.9) | 4.5 | 6.0 | 5.3 (1.1) | 2.0 | 8.0 | 4.5 (3.1) |
| Mac '98 | 3.5 | 15.5 | 9.8 (5.0) | 3.0 | 5.0 | 4.0 (1.4) | 5.0 | 7.0 | 5.7 (1.2) |
| Apr '98 | 6.0 | 10.0 | 8.6 (1.8) | 9.0 | 12.5 | 10.8 92.5) | 5.5 | 11.5 | 9.2 (3.2) |
| Mean | | | 11.7 (5.6) | | | 10.8 (2.7) | | | 13.8 (7.2) |

Note: N/A = Not available

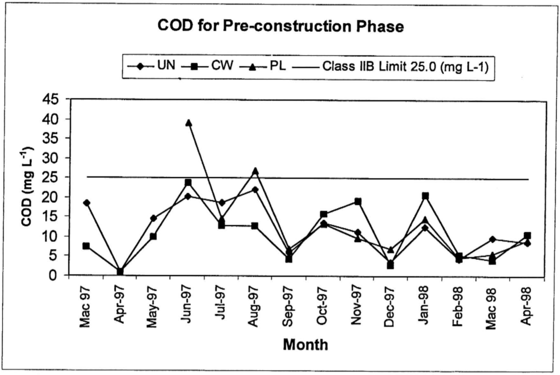


**Figure 46. COD Values (mg $L^{-1}$) for Pre-construction of Wetland Cells**

4.4.1.5 Ammoniacal Nitrogen (AN)

Table 18 shows that the AN values ranged from 0.3 to 4.3 mg $L^{-1}$, 0.3 to 2.8 mg $L^{-1}$ and 0.5 to 2.7 mg $L^{-1}$ for UN, CW and PL. The mean AN recorded for the three sites was 1.2 ± 0.3 mg $L^{-1}$ for UN, 0.9 ± 0.1 mg $L^{-1}$ for CW and 1.1 ± 0.3 mg $L^{-1}$ for PL. The minimum AN was recorded in April 1997 for UN and CW. For PL, the minimum DO was recorded in August 1997. The highest AN was recorded in September 1997 for the three sites. This can be seen from Figure 47 where the highest peak of mean AN was recorded in September 1997.

**Table 18. AN Values (mg $L^{-1}$) for Pre-construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| Mac '97 | 0.6 | 0.7 | 0.7 (0.1) | 0.4 | 0.4 | 0.4 (0.0) | N/A | N/A | N/A |
| Apr '97 | 0.3 | 0.5 | 0.4 (0.1) | 0.3 | 0.3 | 0.3 (0.0) | N/A | N/A | N/A |
| May '97 | 0.6 | 0.8 | 0.7 (0.1) | 0.4 | 0.6 | 0.5 (0.1) | N/A | N/A | N/A |
| June '97 | 1.8 | 2.1 | 1.9 (0.1) | 0.5 | 1.4 | 1.0 (0.6) | 0.7 | 1.8 | 1.3 (0.6) |
| July '97 | 1.1 | 1.4 | 1.3 (0.1) | 1.0 | 1.2 | 1.1 (0.1) | 0.9 | 1.1 | 1.0 (0.1) |
| Aug '97 | 1.8 | 3.9 | 2.8 (0.9) | 1.1 | 1.2 | 1.2 (0.1) | 0.5 | 1.8 | 1.1 (0.7) |
| Sep '97 | 1.2 | 4.3 | 3.4 (1.5) | 2.3 | 2.8 | 2.6 (0.4) | 1.9 | 2.7 | 2.3 (0.4) |
| Oct '97 | 0.7 | 0.8 | 0.8 (0.1) | 0.9 | 1.0 | 1.0 (0.1) | 1.0 | 1.6 | 1.2 (0.3) |
| Nov '97 | 0.5 | 0.8 | 0.7 (0.1) | 0.6 | 0.6 | 0.6 (0.0) | 0.6 | 1.1 | 0.8 (0.3) |
| Dec '97 | 0.7 | 1.0 | 0.9 (0.1) | 0.7 | 0.8 | 0.7 (0.1) | 0.6 | 1.2 | 0.9 (0.3) |
| Jan '98 | 0.5 | 0.8 | 0.7 (0.1) | 0.7 | 0.8 | 0.8 (0.1) | 0.6 | 1.0 | 0.8 (0.2) |
| Feb '98 | 0.6 | 1.0 | 0.8 (0.2) | 0.7 | 1.0 | 0.9 (0.2) | 0.5 | 0.8 | 0.7 (0.2) |
| Mac '98 | 0.9 | 3.6 | 1.8 (1.2) | 1.0 | 1.1 | 1.1 (0.1) | 0.8 | 1.0 | 0.9 (0.1) |
| Apr '98 | 0.4 | 0.5 | 0.5 (0.1) | 0.5 | 0.6 | 0.6 (0.1) | 0.6 | 0.7 | 0.7 (0.1) |
| Mean | | | 1.2 (0.3) | | | 0.9 (0.1) | | | 1.1 (0.3) |

Note: N/A = Not available

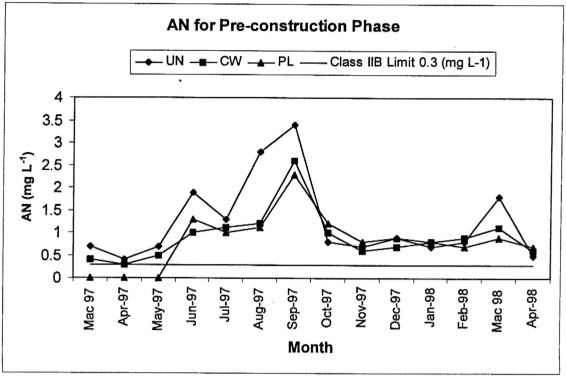


**Figure 47. AN Values (mg $L^{-1}$) for Pre-construction of Wetland Cells**

4.4.1.6 Total Suspended Solids (TSS)

Mean TSS for pre-construction of wetland cells from UN, CW and PL was 378.9 ± 332.9 mg $L^{-1}$, 405.1 ± 187.7 mg $L^{-1}$ and 83.5 ± 235.0 mg $L^{-1}$ respectively (Table 19). The TSS from UN ranged from 7.5 to 4540.0 mg $L^{-1}$ with the minimum and maximum were recorded in April 1998 and March 1998 respectively. For CW, the TSS ranged from 22.5 to 2849.5 mg $L^{-1}$ with the minimum and maximum were recorded in March 1997 and January 1998. The TSS for PL ranged from 29.5 to 2434.5 mg $L^{-1}$ with the minimum and maximum were recorded in September 1997 and January 1998. The trend of TSS for pre-construction of wetland cells is shown in Figure 48. This figure shows two high peak of TSS in January and March 1998 for the three sites.

**Table 19. TSS Values (mg $L^{-1}$) for Pre-construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| Mac '97 | 13.0 | 23.0 | 17.5 (5.0) | 22.5 | 32.0 | 27.3 (6.7) | N/A | N/A | N/A |
| Apr '97 | 7.5 | 52.5 | 31.5 (24.1) | 39.0 | 56.5 | 47.8 (12.4) | N/A | N/A | N/A |
| May '97 | 15.0 | 119.5 | 90.5 (50.4) | 101.5 | 122.0 | 111.8 (14.5) | N/A | N/A | N/A |
| June '97 | 54.5 | 338.0 | 167.0 (120.9) | 178.5 | 276.5 | 227.5 (69.3) | 33.0 | 120.0 | 76.5 (43.5) |
| July '97 | 90.5 | 385.5 | 206.5 (132.8) | 196.5 | 453.0 | 324.8 (181.4) | 124.0 | 217.5 | 178.0 (48.4) |
| Aug '97 | 12.5 | 554.0 | 153.5 (267.1) | 95.0 | 114.5 | 104.8 (13.8) | 71.5 | 224.5 | 134.5 (80.0) |
| Sep '97 | 30.0 | 82.0 | 58.4 (23.6) | 74.0 | 106.0 | 90.0 (22.6) | 29.5 | 35.5 | 32.0 (3.1) |
| Oct '97 | 127.0 | 230.5 | 190.4 (45.8) | 129.0 | 162.0 | 15.5 (23.3) | 97.5 | 370.5 | 277.3 (155.8) |
| Nov '97 | 168.0 | 690.0 | 402.5 (248.5) | 525.5 | 746.0 | 635.8 (155.9) | 56.5 | 266.5 | 143.7 (109.4) |
| Dec '97 | 209.5 | 562.0 | 345.0 (165.5) | 333.0 | 336.0 | 334.5 (2.1) | 49.0 | 467.5 | 202.8 (230.2) |
| Jan '98 | 105.0 | 3224.0 | 925.1 (1533.1) | 1418.0 | 2849.5 | 2133.8 (1012.2) | 42.5 | 2434.5 | 876.8 (1350.1) |
| Feb '98 | 50.0 | 62.5 | 57.0 (6.0) | 66.0 | 129.5 | 97.8 (44.9) | 44.0 | 160.0 | 90.7 (61.2) |
| Mac '98 | 180.5 | 4540.0 | 2635.0 (2024.7) | 505.0 | 2013.5 | 1259.3 (1066.7) | 672.5 | 1504.0 | 1002.8 (441.3) |
| Apr '98 | 13.0 | 40.5 | 24.0 (12.7) | 259.5 | 263.0 | 261.3 (2.5) | 40.0 | 165.0 | 103.2 (62.5) |
| Mean | | | 378.9 (332.9) | | | 405.1 (187.7) | | | 283.5 (235.0) |

Note: N/A = Not available

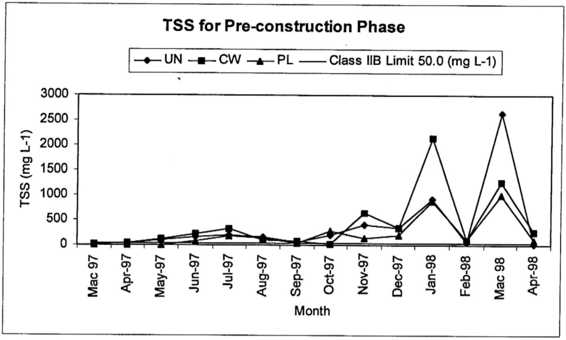


**Figure 48. TSS Values (mg $L^{-1}$) for Pre-construction of Wetland Cells**

4.4.2 During Construction of Wetland Cells

4.4.2.1 pH

Mean pH during construction of wetland cells for UN, CW and PL recorded was 6.6 ± 0.2, 6.7 ± 0.1 and 6.9 ± 0.2 respectively (Table 20). The pH for UN ranged from 5.8 to 7.8 with the minimum and maximum recorded in September 1999 and November 1998 respectively. For CW, the pH ranged from 6.1 to 7.3 with the minimum and maximum were recorded in July 1999 and May 1998. The pH for PL ranged from 5.8 to 7.5 with the minimum and maximum was recorded in December 1998 and June 1998. The trend of pH during construction of wetland cells is shown in Figure 49. This figure shows quite a stable trend over the period of construction of wetland cells.

**Table 20. pH Values During Construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| May '98 | 6.3 | 7.3 | 6.9 (0.3) | 7.3 | 7.3 | 7.3 (0.0) | 7.2 | 7.4 | 7.3 (0.1) |
| June '98 | 7.0 | 7.5 | 7.3 (0.2) | 6.9 | 7.4 | 7.2 (0.4) | 7.5 | 7.5 | 7.5 (0.0) |
| July '98 | 7.0 | 7.5 | 7.2 (0.2) | 7.2 | 7.1 | 7.2 (0.1) | 7.2 | 7.3 | 7.3 (0.1) |
| Aug '98 | 6.6 | 7.3 | 6.7 (0.2) | 6.9 | 7.1 | 7.0 (0.1) | 7.1 | 7.3 | 7.2 (0.1) |
| Sep '98 | 6.7 | 7.1 | 6.9 (0.1) | 6.5 | 6.5 | 6.5 (0.0) | 6.5 | 6.8 | 6.6 (0.2) |
| Oct '98 | 6.15 | 7.1 | 6.7 (0.3 | 6.6 | 6.3 | 6.5 (0.2) | 6.2 | 7.0 | 6.6 (0.4) |
| Nov '98 | 6.6 | 7.8 | 7.0 (0.4) | 6.9 | 7.0 | 7.0 (0.1) | 6.3 | 7.1 | 6.7 (0.4) |
| Dec '98 | 6.4 | 6.7 | 6.5 (0.1) | 6.5 | 6.4 | 6.5 (0.1) | 5.8 | 5.9 | 5.8 (0.0) |
| Jan '99 | 6.2 | 6.6 | 6.4 (0.1) | 6.5 | 6.5 | 6.5 (0.0) | 6.3 | 6.8 | 6.6 (0.2) |
| Feb '99 | 6.4 | 7.0 | 6.7 (0.2) | 6.5 | 6.9 | 6.7 (0.2) | 7.0 | 7.3 | 7.1 (0.1) |
| Mac '99 | 6.1 | 6.4 | 6.2 (0.1) | 6.2 | 6.4 | 6.3 (0.1) | 6.5 | 6.8 | 6.6 (0.1) |
| Apr '99 | 5.9 | 6.6 | 6.4 (0.2) | 6.4 | 6.7 | 6.5 (0.1) | 6.8 | 7.0 | 6.9 (0.1) |
| May '99 | 6.3 | 6.7 | 6.4 (0.2) | 6.6 | 6.8 | 6.7 (0.1) | 6.8 | 7.4 | 7.1 (0.3) |
| June '99 | 6.7 | 7.0 | 6.8 (0.1) | 6.4 | 6.5 | 6.4 (0.1) | 7.0 | 7.3 | 7.1 (0.2) |
| July '99 | 6.1 | 6.5 | 6.2 (0.1) | 6.1 | 6.3 | 6.2 (0.1) | 6.4 | 6.9 | 6.6 (0.2) |
| Aug '99 | 6.1 | 6.5 | 6.3 (0.2) | 6.4 | 6.4 | 6.4 (0.0) | 6.5 | 6.7 | 6.6 (0.1) |
| Sep '99 | 5.8 | 6.7 | 6.3 (0.3) | 6.3 | 6.6 | 6.4 (0.1) | 6.7 | 7.1 | 7.0 (0.2) |
| Mean | | | 6.6 (0.2) | | | 6.7 (0.1) | | | 6.9 (0.2) |

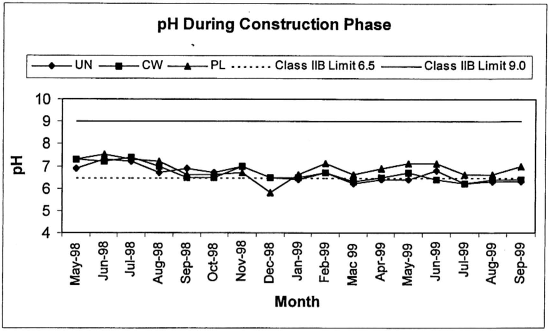


**Figure 49. pH Values During Construction of Wetland Cells**

4.4.2.2 Dissolved Oxygen (DO)

Table 21 shows the DO for UN, CW and PL ranged from 4.2 to 7.1 mg $L^{-1}$, 5.2 to 7.0 mg $L^{-1}$ and 4.5 to 7.0 mg $L^{-1}$. The mean DO recorded was 5.9 ± 0.4 mg $L^{-1}$, 6.2 ± 0.2 mg $L^{-1}$ and 6.0 ± 0.2 mg $L^{-1}$ for UN, CW and PL respectively. The minimum DO was recorded for UN, CW and PL was in June 1999, August 1998 and December 1998 respectively. The highest DO was recorded in July 1998 for UN, November 1998 and June 1999 for CW and May and June 1999 for PL. The trend of DO for UN, CW and PL during construction of wetland cells is shown in Figure 50. The DO fluctuated within the range of Class IIB limits of 5 – 7 mg $L^{-1}$ except for DO in PL which was below 5 mg $L^{-1}$ in September 1998.

**Table 21. DO Values (mg $L^{-1}$) During Construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| May '98 | 4.7 | 6.8 | 6.0 (0.7) | 6.3 | 6.6 | 6.5 (0.2) | 6.3 | 6.6 | 6.5 (0.2) |
| June '98 | 6.2 | 7.0 | 6.6 (0.3) | 5.6 | 6.1 | 5.9 (0.4) | 5.9 | 6.1 | 6.0 (0.1) |
| July '98 | 6.0 | 7.1 | 6.4 (0.4) | 6.2 | 6.3 | 6.3 (0.1) | 5.7 | 6.5 | 6.0 (0.4) |
| Aug '98 | 4.9 | 5.7 | 5.4 (0.3) | 5.2 | 5.8 | 5.5 (0.4) | 5.5 | 5.6 | 5.5 (0.1) |
| Sep '98 | 5.4 | 6.4 | 5.9 (0.4) | 5.2 | 5.5 | 5.4 (0.2) | 4.7 | 5.0 | 4.8 (0.2) |
| Oct '98 | 5.6 | 6.5 | 6.2 (0.3) | 6.5 | 6.7 | 6.6 (0.1) | 6.0 | 6.4 | 6.2 (0.2) |
| Nov '98 | 5.1 | 6.9 | 5.9 (0.6) | 6.6 | 7.0 | 6.8 (0.3) | 5.4 | 5.6 | 5.5 (0.1) |
| Dec '98 | 5.1 | 5.8 | 5.3 (0.2) | 5.5 | 5.8 | 5.7 (0.2) | 4.5 | 9.6 | 6.2 (2.9) |
| Jan '99 | 5.7 | 6.8 | 6.3 (0.4) | 6.3 | 6.6 | 6.4 (0.2) | 5.4 | 5.7 | 5.5 (0.2) |
| Feb '99 | 5.7 | 6.0 | 5.8 (0.1) | 5.6 | 6.1 | 5.9 (0.2) | 6.0 | 6.7 | 6.4 (0.4) |
| Mac '99 | 4.9 | 6.0 | 5.5 (0.4) | 5.7 | 6.5 | 6.1 (0.4) | 6.1 | 6.4 | 6.2 (0.1) |
| Apr '99 | 5.1 | 6.3 | 5.8 (0.4) | 5.9 | 6.4 | 6.2 (0.2) | 5.5 | 6.4 | 5.9 (0.4) |
| May '99 | 5.4 | 6.3 | 5.8 (0.3) | 6.1 | 6.5 | 6.2 (0.2) | 5.8 | 7.0 | 6.3 (0.5) |
| June '99 | 4.2 | 6.6 | 6.0 (0.8) | 6.5 | 7.0 | 6.8 (0.2) | 6.3 | 7.0 | 6.7 (0.3) |
| July '99 | 5.4 | 6.7 | 6.2 (0.5) | 6.4 | 6.8 | 6.6 (0.2) | 6.7 | 6.8 | 6.7 (0.0) |
| Aug '99 | 5.3 | 6.1 | 5.6 (0.3) | 6.2 | 6.6 | 6.3 (0.1) | 6.2 | 6.7 | 6.4 (0.2) |
| Sep '99 | 5.0 | 6.5 | 6.0 (0.5) | 6.1 | 6.5 | 6.2 (0.2) | 6.7 | 6.9 | 6.8 (0.1) |
| Mean | | | 5.9 (0.4) | | | 6.2 (0.2) | | | 6.0 (0.2) |

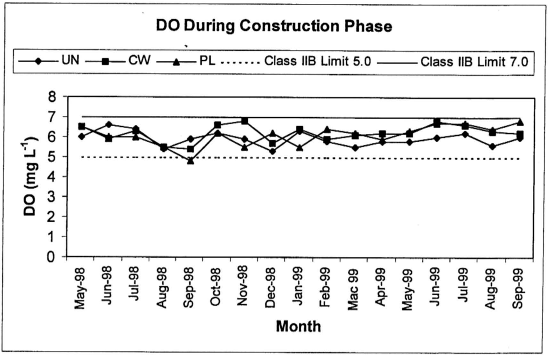


**Figure 50. DO Values (mg $L^{-1}$) During Construction of Wetland Cells**

4.4.2.3 Biochemical Oxygen Demand (BOD)

The mean BOD for UN, CW and PL recorded was 2.3 ± 0.4 mg $L^{-1}$, 2.5 ± 0.4 mg $L^{-1}$, 2.6 ± 0.4 mg $L^{-1}$ respectively (Table 22). The BOD during construction of wetland cells for UN, ranged from 2.0 to 6.9 mg $L^{-1}$ with the maximum were recorded in November 1998. The minimum BOD recorded for UN during construction of wetland cells was 2.0 mg $L^{-1}$ except for the month of November 1998 where BOD recorded was 3.2 mg $L^{-1}$. In CW and PL, the BOD ranged from 2.0 to 5.4 mg $L^{-1}$ and 2.0 to 7.5 mg $L^{-1}$ respectively. The minimum BOD for CW and PL recorded during construction of wetland cells was 2.0 mg $L^{-1}$. The maximum BOD recorded for UN, CW and PL was in November, October and December 1998 respectively.

Based on Figure 51, the mean BOD trend was stable for the three sites from May to August 1998. The highest peak of mean BOD was recorded for PL in September 1999 and this is followed by the second peak which occurred in December 1999. For UN and CW, the highest peak of mean BOD was recorded from October to December 1998. The mean BOD for the three sites decreased gradually after January 1999.

**Table 22. BOD Values (mg $L^{-1}$) During Construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| May '98 | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.0 | 2.0 (0.0) |
| June '98 | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.0 | 2.0 (0.0) |
| July '98 | 2.0 | 2.2 | 2.0 (0.1) | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.0 | 2.0 (0.0) |
| Aug '98 | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.0 | 2.0 (0.0) |
| Sep '98 | 2.0 | 2.5 | 2.1 (0.2) | 2.0 | 2.1 | 2.1 (0.1) | 5.8 | 7.7 | 6.6 (1.0) |
| Oct '98 | 2.0 | 4.5 | 3.1 (1.1) | 2.4 | 5.4 | 3.9 (2.1) | 2.0 | 2.4 | 2.1 (0.2) |
| Nov '98 | 3.2 | 6.9 | 4.4 (1.3) | 3.7 | 4.8 | 4.3 (0.8) | 3.5 | 4.0 | 3.7 (0.3) |
| Dec '98 | 2.0 | 2.7 | 2.2 (0.3) | 2.9 | 5.2 | 4.0 (1.7) | 2.1 | 7.5 | 4.3 (2.3) |
| Jan '99 | 2.0 | 4.0 | 2.3 (0.7) | 2.2 | 2.9 | 2.5 (0.5) | 2.0 | 2.5 | 2.3 (0.3) |
| Feb '99 | 2.0 | 4.0 | 2.4 (0.7) | 2.0 | 2.9 | 2.3 (0.4) | 2.0 | 3.5 | 2.6 (0.8) |
| Mac '99 | 2.0 | 5.2 | 3.3 (1.2) | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.0 | 2.0 (0.0) |
| Apr '99 | 2.0 | 2.9 | 2.3 (0.3) | 2.5 | 2.9 | 2.6 (0.2) | 2.0 | 3.2 | 2.3 (0.6) |
| May '99 | 2.0 | 2.4 | 2.1 (0.1) | 2.0 | 3.4 | 2.3 (0.7) | 2.0 | 3.3 | 2.6 (0.6) |
| June '99 | 2.0 | 2.5 | 2.1 (0.2) | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.2 | 2.0 (0.1) |
| July '99 | 2.0 | 3.1 | 2.3 (0.4) | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.1 | 2.0 (0.0) |
| Aug '99 | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.2 | 2.0 (0.1) | 2.1 | 2.4 | 2.2 (0.1) |
| Sep '99 | 2.0 | 2.4 | 2.1 (0.1) | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.2 | 2.1 (0.1) |
| Mean | | | 2.3 (0.4) | | | 2.5 (0.4) | | | 2.6 (0.4) |

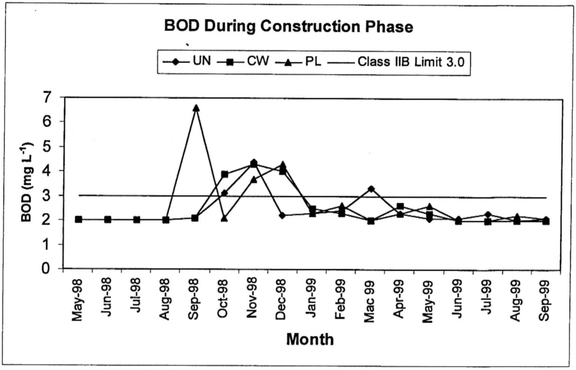


**Figure 51. BOD Values (mg $L^{-1}$) During Construction of Wetland Cells**

4.4.2.4 Chemical Oxygen Demand (COD)

The COD concentrations in UN, CW and PL are shown in Table 23. The COD ranged from 1.0 to 22.0 mg $L^{-1}$, 1.0 to 19.5 mg $L^{-1}$ and 1.0 to 22.0 mg $L^{-1}$ for UN, CW and PL respectively. In UN, the minimum COD was recorded in May and June 1998, January 1999 and July to September 1999. The maximum COD of 22.0 mg $L^{-1}$ for UN was recorded in June 1999. The minimum COD was recorded in June 1998 and August 1999 for CW and June 1998 and March 1999 for PL. The maximum COD for CW and PL was recorded in August 1999 and December 1998 respectively. In UN, CW and PL, the mean COD was 7.9 ± 4.0 mg $L^{-1}$, 7.5 ± 3.1 and 8.2 ± 3.1 mg $L^{-1}$ respectively. Figure 52 shows the trend of mean COD during construction period. The mean COD fluctuated during the construction of wetland cells. However, all the mean COD values were well within the Class IIB limits of 25.0 mg $L^{-1}$.

**Table 23. COD Values (mg $L^{-1}$) During Construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| May '98 | 1.0 | 14.5 | 5.7 (4.4) | 5.0 | 6.0 | 5.5 (0.7) | 5.5 | 6.0 | 5.7 (0.3) |
| June '98 | 1.0 | 4.5 | 3.5 (1.1) | 1.0 | 2.0 | 1.5 (0.7) | 1.0 | 12.5 | 5.7 (6.0) |
| July '98 | 4.0 | 11.0 | 6.9 (2.5) | 2.5 | 5.5 | 4.0 (2.1) | 4.0 | 5.0 | 4.7 (0.6) |
| Aug '98 | 6.0 | 12.0 | 8.6 (1.9) | 7.0 | 8.0 | 7.5 (7.7) | 2.0 | 7.5 | 4.2 (2.9) |
| Sep '98 | 4.0 | 10.0 | 5.6 (2.1) | 5.0 | 7.0 | 6.0 (1.4) | 16.0 | 18.5 | 17.3 (1.3) |
| Oct '98 | 4.0 | 12.0 | 9.1 (2.7) | 7.5 | 16.0 | 11.8 (6.0) | 5.0 | 9.0 | 7.7 (2.3) |
| Nov '98 | 7.5 | 19.0 | 12.3 (4.3) | 8.5 | 12.0 | 10.3 (2.5) | 8.5 | 11.5 | 10.5 (1.7) |
| Dec '98 | 4.0 | 8.5 | 6.4 (1.6) | 11.0 | 15.5 | 13.3 (3.2) | 5.5 | 22.0 | 11.8 (8.9) |
| Jan '99 | 1.0 | 16.0 | 5.0 (4.9) | 4.5 | 7.5 | 6.0 (2.1) | 2.0 | 3.5 | 3.0 (0.9) |
| Feb '99 | 4.0 | 12.5 | 8.5 (3.6) | 6.5 | 10.5 | 7.8 (1.8) | 3.0 | 12.0 | 8.0 (3.9) |
| Mac '99 | 2.0 | 18.5 | 8.8 (5.5) | 1.5 | 5.0 | 2.9 (1.5) | 1.0 | 5.0 | 3.4 (1.7) |
| Apr '99 | 2.0 | 14.0 | 6.9 (3.8) | 3.5 | 8.0 | 5.9 (1.9) | 4.0 | 12.5 | 7.8 (3.8) |
| May '99 | 2.5 | 20.0 | 8.3 (5.9) | 3.5 | 8.0 | 5.9 (1.9) | 6.0 | 13.5 | 8.0 (3.7) |
| June '99 | 3.5 | 22.0 | 13.4 (6.8) | 7.5 | 14.5 | 9.8 (3.3) | 5.0 | 16.0 | 8.4 (5.2) |
| July '99 | 1.0 | 17.0 | 7.4 (5.2) | 9.0 | 15.5 | 10.9 (3.1) | 4.5 | 12.5 | 7.4 (3.5) |
| Aug '99 | 1.0 | 15.5 | 9.2 (5.1) | 1.0 | 19.5 | 7.9 (8.7) | 9.0 | 18.5 | 12.6 (4.1) |
| Sep '99 | 1.0 | 17.5 | 9.5 (6.1) | 6.0 | 14.5 | 10.3 (3.8) | 10.9 | 15.5 | 14.0 (2.4) |
| Mean | | | 7.9 (4.0) | | | 7.5 (3.1) | | | 8.2 (3.1) |

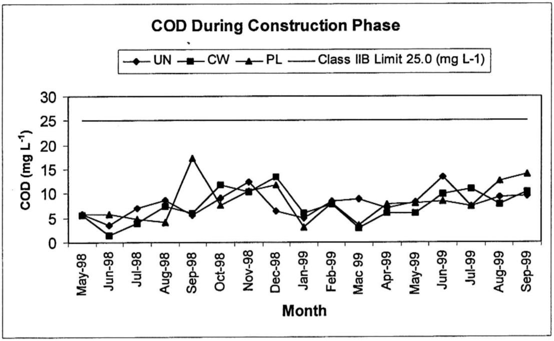


**Figure 52. COD Values (mg $L^{-1}$) During Construction of Wetland Cells**

4.4.2.5 Ammoniacal Nitrogen (AN)

Mean AN during construction of wetland cells from UN, CW and PL was 0.3 ± 0.2 mg $L^{-1}$, 0.3 ± 0.1 mg $L^{-1}$ and 0.4 ± 0.1 mg $L^{-1}$ respectively (Table 24). The AN for UN ranged from 0.1 to 1.3 mg $L^{-1}$ with the minimum was recorded in July and September 1998, November to February 1999 and August to September 1999 respectively. The maximum AN for UN was recorded in August 1998. For CW, the AN ranged from 0.1 to 0.7 with the minimum was recorded in August and December 1998, August to September 1999 and May 1998 and maximum was recorded in September 1998. The AN for PL ranged from 0.1 to 1.3 mg $L^{-1}$ with the minimum recorded in February, May, August and September 1999 and the maximum recorded in November 1998. Figure 53 indicated the peak of mean AN at 1.3 mg $L^{-1}$ during construction of wetland cells for

PL. Overall, the trend of mean AN was not stable and fluctuated for the whole period of construction of wetland cells.

**Table 24. AN Values (mg $L^{-1}$) During Construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| May '98 | 0.2 | 0.6 | 0.3 (0.1) | 0.4 | 0.5 | 0.5 (0.1) | 0.4 | 0.5 | 0.5 (0.1) |
| June '98 | 0.2 | 0.9 | 0.4 (0.3) | 0.2 | 0.3 | 0.3 (0.1) | 0.3 | 0.5 | 0.4 (0.1) |
| July '98 | 0.1 | 0.5 | 0.2 (0.1) | 0.2 | 0.5 | 0.4 (0.2) | 0.5 | 0.6 | 0.6 (0.1) |
| Aug '98 | 0.2 | 1.3 | 0.5 (0.4) | 0.1 | 0.4 | 0.3 (0.2) | 0.2 | 0.3 | 0.3 (0.1) |
| Sep '98 | 0.1 | 0.7 | 0.3 (0.2) | 0.2 | 0.7 | 0.5 (0.4) | 0.5 | 0.7 | 0.6 (0.1) |
| Oct '98 | 0.2 | 0.5 | 0.3 (0.1) | 0.2 | 0.4 | 0.3 (0.1) | 0.5 | 0.9 | 0.7 (0.2) |
| Nov '98 | 0.1 | 0.4 | 0.2 (0.1) | 0.2 | 0.2 | 0.2 (0.0) | 1.1 | 1.3 | 1.2 (0.1) |
| Dec '98 | 0.1 | 1.0 | 0.3 (0.3) | 0.1 | 0.2 | 0.1 (0.0) | 0.2 | 0.3 | 0.2 (0.0) |
| Jan '99 | 0.1 | 0.8 | 0.4 (0.3) | 0.2 | 0.3 | 0.3 (0.1) | 0.2 | 0.3 | 0.2 (0.1) |
| Feb '99 | 0.1 | 0.6 | 0.2 (0.2) | 0.2 | 0.3 | 0.2 (0.1) | 0.1 | 0.2 | 0.1 (0.0) |
| Mac '99 | 0.2 | 0.7 | 0.3 (0.2) | 0.2 | 0.3 | 0.3 (0.1) | 0.2 | 0.3 | 0.2 (0.0) |
| Apr '99 | 0.2 | 0.5 | 0.3 (0.1) | 0.3 | 0.5 | 0.3 (0.1) | 0.3 | 0.4 | 0.3 (0.1) |
| May '99 | 0.2 | 0.5 | 0.3 (0.1) | 0.2 | 0.2 | 0.2 (0.0) | 0.1 | 0.2 | 0.1 (0.1) |
| June '99 | 0.3 | 0.6 | 0.4 (0.1) | 0.2 | 0.4 | 0.3 (0.1) | 0.3 | 0.5 | 0.4 (0.1) |
| July '99 | 0.5 | 1.1 | 0.7 (0.2) | 0.4 | 0.5 | 0.5 (0.0) | 0.2 | 0.4 | 0.3 (0.1) |
| Aug '99 | 0.1 | 0.4 | 0.2 (0.1) | 0.1 | 0.2 | 0.1 (0.0) | 0.1 | 0.1 | 0.1 (0.0) |
| Sep '99 | 0.1 | 0.7 | 0.2 (0.2) | 0.1 | 0.2 | 0.1 (0.1) | 0.1 | 0.1 | 0.1 (0.0) |
| Mean | | | 0.3 (0.2) | | | 0.3 (0.1) | | | 0.4 (0.1) |

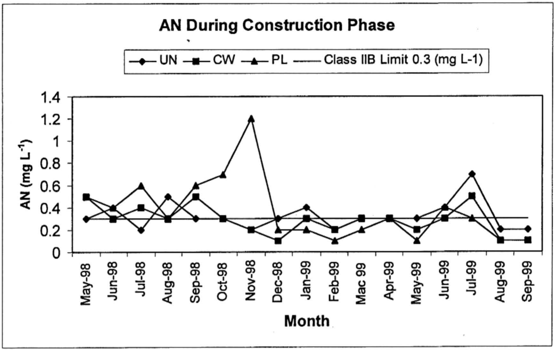


**Figure 53. AN Values (mg $L^{-1}$) During Construction of Wetland Cells**

4.4.2.6 Total Suspended Solids (TSS)

Table 25 shows the mean TSS during construction of wetland cells for UN, CW and PL was 18.7 ± 9.9 mg $L^{-1}$, 47.3 ± 23.8 mg $L^{-1}$ and 142.1 ± 109.9 mg $L^{-1}$ respectively. The TSS for UN ranged from 4.0 to 72.0 mg $L^{-1}$ with the minimum recorded in November 1998 and September 1999 and maximum recorded in July 1998 respectively. For CW, the TSS ranged from 4.0 to 612.0 mg $L^{-1}$ with the minimum and maximum were recorded in September 1999 and June 1998. The TSS for PL ranged from 4.5 to 2142.5 mg $L^{-1}$ with the minimum and maximum was recorded in September 1999 and June 1998. The trend of mean TSS during construction of wetland cells is shown in Figure 54. This figure shows two high peaks of mean TSS in June and September 1998 for PL. The TSS gradually declined after November 1998 for the three sites.

**Table 25. TSS Values (mg $L^{-1}$) During Construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| May '98 | 11.0 | 61.5 | 22.1 (16.3) | 59.0 | 76.0 | 67.5 (12.0) | 61.0 | 215.5 | 148.8 (79.4) |
| June '98 | 11.5 | 55.0 | 29.3 (16.8) | 167.5 | 612.0 | 389.8 (314.3) | 64.0 | 2142.5 | 1215.7 (1057.3) |
| July '98 | 8.0 | 72.0 | 29.1 (20.4) | 40.0 | 59.5 | 49.8 (13.8) | 37.5 | 58.0 | 45.7 (10.9) |
| Aug '98 | 6.0 | 58.5 | 18.8 (18.4) | 87.5 | 90.0 | 88.8 (1.8) | 93.0 | 288.0 | 221.2 (111.0) |
| Sep '98 | 10.0 | 42.5 | 18.9 (13.7) | 33.5 | 34.0 | 33.8 (0.4) | 103.5 | 647.5 | 378.7 (272.1) |
| Oct '98 | 6.0 | 31.0 | 12.4 (9.0) | 16.0 | 18.0 | 17.0 (1.4) | 46.5 | 513.0 | 212.7 (260.6) |
| Nov '98 | 4.0 | 17.5 | 8.1 (4.3) | 7.5 | 9.0 | 8.3 (1.1) | 17.5 | 50.5 | 33.2 (16.6) |
| Dec '98 | 10.5 | 59.5 | 27.5 (18.1) | 13.5 | 17.0 | 15.3 (2.5) | 19.5 | 59.0 | 34.5 (21.4) |
| Jan '99 | 8.0 | 32.0 | 13.6 (7.9) | 19.5 | 24.5 | 22.0 (3.5) | 18.0 | 26.5 | 21.3 (4.5) |
| Feb '99 | 10.0 | 19.5 | 13.8 (3.7) | 6.5 | 24.5 | 14.0 (7.6) | 7.0 | 12.5 | 9.6 (2.8) |
| Mac '99 | 17.0 | 45.0 | 26.6 (9.3) | 5.5 | 18.5 | 9.6 (6.0) | 7.0 | 18.0 | 11.5 (4.7) |
| Apr '99 | 13.0 | 36.0 | 20.7 (6.9) | 9.5 | 23.5 | 15.1 (5.9) | 11.0 | 22.0 | 16.3 (5.6) |
| May '99 | 9.5 | 20.5 | 14.6 (3.7) | 7.5 | 22.5 | 14.5 (6.3) | 6.5 | 13.0 | 10.4 (3.0) |
| June '99 | 11.0 | 25.0 | 20.5 (5.2) | 8.0 | 51.0 | 26.3 (18.0) | 7.5 | 14.5 | 10.5 (3.0) |
| July '99 | 17.5 | 32.5 | 22.7 (5.2) | 12.0 | 23.0 | 15.3 (5.2) | 15.5 | 36.0 | 27.0 (8.6) |
| Aug '99 | 5.5 | 19.0 | 11.9 (4.6) | 10.0 | 12.5 | 11.3 (1.2) | 7.0 | 17.0 | 12.0 (5.2) |
| Sep '99 | 4.0 | 20.5 | 7.1 (5.5) | 4.0 | 10.5 | 6.0 (3.0) | 4.5 | 10.0 | 7.4 (2.4) |
| Mean | | | 18.7 (9.9) | | | 47.3 (23.8) | | | 142.1 (109.9) |

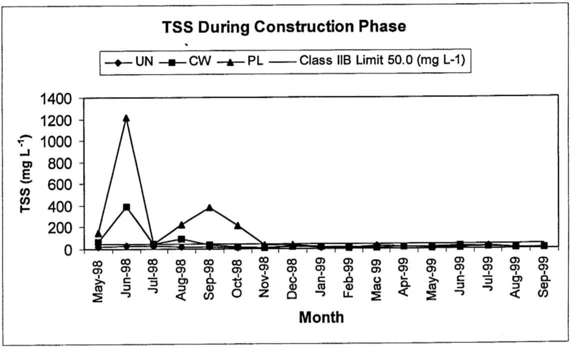


**Figure 54. TSS Values (mg $L^{-1}$) During Construction of Wetland Cells**

4.4.3 After Construction of Wetland Cells

4.4.3.1 pH

The mean pH for UN, CW and PL recorded after construction of wetland cells was 6.0 $\pm$ 0.2 mg $L^{-1}$, 6.3 $\pm$ 0.3 mg $L^{-1}$, 6.5 $\pm$ 0.3 mg $L^{-1}$ respectively (Table 26). The pH for UN ranged from 5.2 to 6.9 mg $L^{-1}$ with the minimum and maximum was recorded in July 2000 and November 1999 respectively. In CW and PL, the pH ranged from 5.6 to 7.7 mg $L^{-1}$ and 5.5 to 8.0 mg $L^{-1}$ respectively. The minimum pH for CW and PL was recorded in July 2000 and the maximum was recorded in November 1999 respectively.

Based on Figure 55, the mean pH trend was stable (with minor changes) for the three sites after construction of wetland cells.

**Table 26. pH Values After Construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| Oct '99 | 5.4 | 6.4 | 6.1 (0.3) | 6.0 | 6.5 | 6.2 (0.2) | 6.2 | 6.9 | 6.5 (0.3) |
| Nov '99 | 6.0 | 6.9 | 6.4 (0.3) | 6.7 | 7.7 | 7.2 (0.6) | 6.3 | 8.0 | 7.2 (0.7) |
| Dec '99 | 6.0 | 6.3 | 6.2 (0.1) | 6.3 | 6.5 | 6.4 (0.1) | 6.2 | 7.1 | 6.7 (0.3) |
| Jan '00 | 5.6 | 6.2 | 6.0 (0.2) | 5.9 | 6.5 | 6.3 (0.3) | 6.3 | 7.6 | 7.0 (0.4) |
| Feb '00 | 5.6 | 6.1 | 5.9 (0.2) | 6.1 | 6.9 | 6.5 (0.4) | 6.2 | 6.8 | 6.5 (0.2) |
| Mac '00 | 5.7 | 6.2 | 6.0 (0.2) | 5.8 | 6.2 | 6.0 (0.2) | 5.9 | 6.8 | 6.3 (0.3) |
| Apr '00 | 5.8 | 6.4 | 6.0 (0.2) | 5.8 | 6.7 | 6.2 (0.4) | 5.9 | 6.4 | 6.1 (0.2) |
| May '00 | 6.0 | 6.3 | 6.1 (0.1) | 6.1 | 6.7 | 6.4 (0.3) | 6.2 | 7.1 | 6.7 (0.4) |
| June '00 | 5.5 | 6.2 | 5.8 (0.3) | 5.8 | 6.5 | 6.1 (0.3) | 6.0 | 7.0 | 6.5 (0.3) |
| July '00 | 5.2 | 6.1 | 5.9 (0.3) | 5.6 | 6.2 | 6.0 (0.3) | 5.5 | 6.2 | 5.9 (0.2) |
| Mean | | | 6.0 (0.2) | | | 6.3 (0.3) | | | 6.5 (0.3) |

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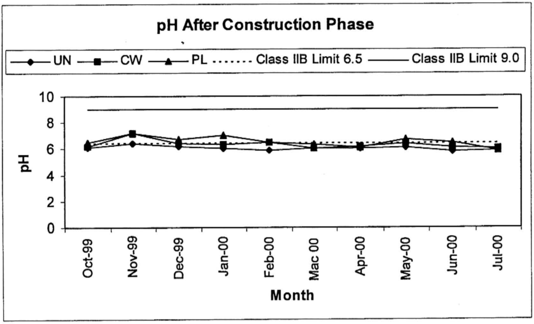


**Figure 55. pH Values After Construction of Wetland Cells**

4.4.3.2 Dissolved Oxygen (DO)

The mean DO recorded was 5.7 ± 0.4 mg $L^{-1}$, 6.3 ± 0.4 mg $L^{-1}$ and 6.3 ± 0.4 mg $L^{-1}$ for UN, CW and PL respectively. Table 27 shows the DO for UN, CW and PL ranged from 3.8 to 7.2 mg $L^{-1}$, 5.5 to 7.5 mg $L^{-1}$ and 4.9 to 7.8 mg $L^{-1}$. The minimum and maximum DO recorded for UN was in January 1997. For CW the minimum DO was recorded in January, February and June 2000. The maximum DO for CW was recorded in April 2000. For PL, the minimum and maximum DO was recorded in February 2000 and April 2000 respectively. Figure 56 shows the trends of DO at UN, CW and PL respectively. The mean DO fluctuated within the Class IIB limit of 5 – 7 mg $L^{-1}$ except for the mean DO in UN. There are two lowest values observed in the month of January and June 2000.

**Table 27. DO Values (mg $L^{-1}$) After Construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| Oct '99 | 5.8 | 6.7 | 6.2 (0.3) | 6.2 | 7.1 | 6.7 (0.4) | 6.5 | 6.8 | 6.7 (0.1) |
| Nov '99 | 5.7 | 6.3 | 6.0 (0.2) | 5.9 | 6.3 | 6.1 (0.2) | 5.6 | 6.0 | 5.8 (0.2) |
| Dec '99 | 5.0 | 7.0 | 6.1 (0.6) | 5.6 | 6.8 | 6.3 (0.6) | 5.6 | 7.0 | 6.5 (0.5) |
| Jan '00 | 3.8 | 4.9 | 4.4 (0.4) | 5.5 | 6.9 | 6.2 (0.7) | 5.1 | 6.2 | 5.8 (0.3) |
| Feb '00 | 4.5 | 6.0 | 5.3 (0.5) | 5.5 | 6.3 | 5.9 (0.3) | 4.9 | 6.3 | 5.6 (0.5) |
| Mac '00 | 5.4 | 6.7 | 6.2 (0.4) | 6.0 | 6.8 | 6.3 (0.3) | 6.1 | 6.9 | 6.4 (0.3) |
| Apr '00 | 5.2 | 6.3 | 5.8 (0.4) | 5.8 | 7.5 | 6.4 (0.7) | 5.9 | 7.8 | 7.0 (0.6) |
| May '00 | 5.5 | 6.2 | 5.8 (0.3) | 5.6 | 6.5 | 6.1 (0.4) | 5.7 | 6.3 | 6.0 (0.2) |
| June '00 | 4.2 | 5.3 | 4.6 (0.3) | 5.5 | 6.3 | 5.9 (0.3) | 5.5 | 6.8 | 6.2 (0.4) |
| July '00 | 5.4 | 7.2 | 6.3 (0.5) | 6.3 | 7.1 | 6.6 (0.4) | 5.9 | 7.4 | 6.6 (0.4) |
| Mean | | | 5.7 (0.4) | | | 6.3 (0.4) | | | 6.3 (0.4) |

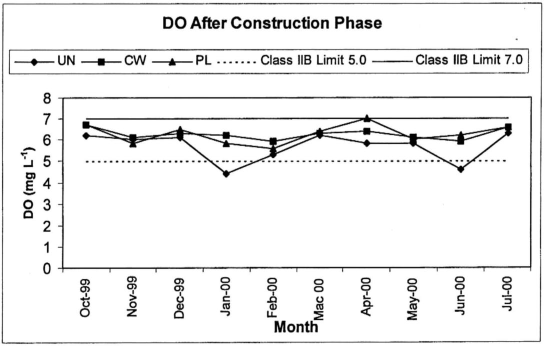


**Figure 56. DO Values (mg $L^{-1}$) After Construction of Wetland Cells**

4.4.3.3 Biochemical Oxygen Demand (BOD)

The mean BOD recorded for both UN and CW after construction of wetland cells was $2.2 \pm 0.2$ mg $L^{-1}$. As for PL, the mean BOD recorded was $2.2 \pm 0.4$ mg $L^{-1}$ (Table 28). The BOD for UN ranged from 2.0 to 4.2 mg $L^{-1}$ with the maximum recorded in July 2000. The minimum BOD recorded for UN after construction of wetland cells was 2.0 mg $L^{-1}$ except for the month of November 1999 where BOD recorded was 2.5 mg $L^{-1}$. In CW and PL, the BOD ranged from 1.2 to 4.3 mg $L^{-1}$ and 1.4 to 7.1 mg $L^{-1}$ respectively. The minimum BOD for CW and PL recorded during construction of wetland cells was 1.2 mg $L^{-1}$ and 1.4 mg $L^{-1}$ respectively. The maximum BOD recorded for UN, CW and PL was in July, June and April 2000 respectively. Based on the Figure 57, the mean BOD trend was fluctuating for this phase for the three sites. The highest peak of BOD was recorded for CW in June 2000.

**Table 28. BOD Values (mg $L^{-1}$) After Construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| Oct '99 | 2.0 | 2.0 | 2.0 (0.0) | 1.2 | 2.4 | 2.0 (0.6) | 2.0 | 2.0 | 2.0 (0.0) |
| Nov '99 | 2.5 | 4.1 | 3.1 (0.6) | 1.2 | 2.4 | 2.0 (0.6) | 1.4 | 2.2 | 1.8 (0.4) |
| Dec '99 | 2.0 | 2.9 | 2.2 (0.3) | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.0 | 2.0 (0.0) |
| Jan '00 | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.6 | 2.2 (0.2) |
| Feb '00 | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.3 | 2.0 (0.1) |
| Mac '00 | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.1 | 2.0 (0.0) |
| Apr '00 | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.1 | 2.0 (0.1) | 2.0 | 7.1 | 3.1 (2.1) |
| May '00 | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.0 | 2.0 (0.0) | 2.0 | 2.9 | 2.2 (0.3) |
| June '00 | 2.0 | 2.0 | 2.0 (0.0) | 2.7 | 4.3 | 3.5 (0.7) | 2.0 | 3.9 | 2.4 (0.7) |
| July '00 | 2.0 | 4.2 | 2.3 (0.8) | 2.0 | 3.0 | 2.3 (0.5) | 2.0 | 2.0 | 2.0 (0.0) |
| Mean | | | 2.2 (0.2) | | | 2.2 (0.2) | | | 2.2 (0.4) |

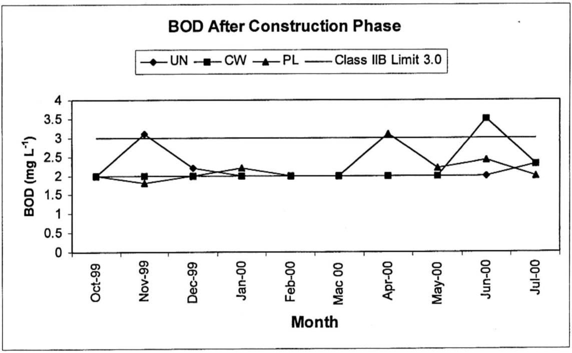


**Figure 57. BOD Values (mg $L^{-1}$) After Construction of Wetland Cells**

4.4.3.4 Chemical Oxygen Demand (COD)

Table 29 shows the COD Concentrations in UN, CW and PL. The COD ranged from 1.0 to 21.0 mg $L^{-1}$, 1.0 to 27.0 mg $L^{-1}$ and 1.0 to 28.0 mg $L^{-1}$ for UN, CW and PL respectively. In UN, CW and PL, most of the minimum COD recorded after construction of wetland cells was 1.0 mg $L^{-1}$ except certain months. The maximum COD of 21.0 mg $L^{-1}$ for UN was recorded in October 1999 and January 2000. The maximum COD recorded for CW and PL was in March and February 2000 respectively. The mean COD for UN, CW and PL was 7.1 ± 5.1 mg $L^{-1}$, 8.1 ± 7.0 and 7.5 ± 5.4 mg $L^{-1}$ respectively. Figure 58 shows the trend of mean COD fluctuated within the Class IIB limits of 25.0 mg $L^{-1}$ after construction of wetland cells.

**Table 29. COD Values (mg $L^{-1}$) After Construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| Oct '99 | 1.0 | 21.0 | 9.0 (8.5) | 1.0 | 18.0 | 5.3 (8.5) | 1.0 | 3.0 | 1.5 (1.0) |
| Nov '99 | 6.5 | 12.2 | 9.4 (2.1) | 4.1 | 11.4 | 6.8 (3.4) | 4.9 | 12.7 | 7.7 (3.4) |
| Dec '99 | 1.0 | 19.0 | 6.0 (6.5) | 1.0 | 23.0 | 6.8 (10.8) | 1.0 | 18.0 | 5.8 (6.9) |
| Jan '00 | 1.0 | 21.0 | 9.4 (6.6) | 1.0 | 1.0 | 1.0 (0.0) | 7.0 | 21.0 | 15.4 (5.0) |
| Feb '00 | 5.0 | 19.0 | 10.6 (5.0) | 6.0 | 20.0 | 13.8 (5.9) | 4.0 | 28.0 | 15.0 (8.8) |
| Mac '00 | 1.0 | 5.0 | 1.5 (1.4) | 1.0 | 27.0 | 8.5 (12.5) | 1.0 | 17.0 | 6.8 (5.3) |
| Apr '00 | 1.0 | 10.0 | 4.1 (3.6) | 1.0 | 19.0 | 7.8 (8.6) | 1.0 | 15.0 | 7.2 (5.7) |
| May '00 | 1.0 | 14.0 | 5.8 (5.7) | 1.0 | 7.0 | 4.8 (2.3) | 1.0 | 22.0 | 6.2 (6.9) |
| June '00 | 1.0 | 15.0 | 6.1 (4.7) | 11.0 | 21.0 | 16.5 (4.2) | 1.0 | 23.0 | 8.0 (8.9) |
| July '00 | 1.0 | 17.0 | 8.6 (6.7) | 1.0 | 24.0 | 12.5 (13.3) | 1.0 | 7.0 | 1.6 (1.9) |
| Mean | | | 7.1 (5.1) | | | 8.1 (7.0) | | | 7.5 (5.4) |

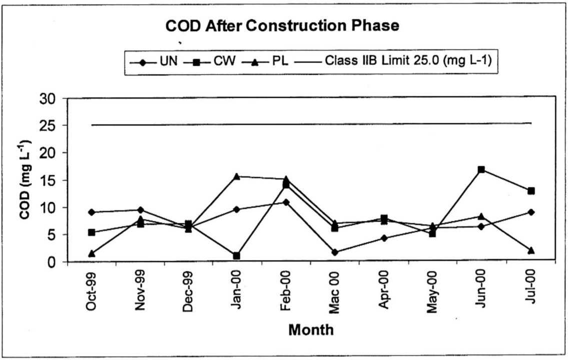


**Figure 58. COD Values (mg $L^{-1}$) After Construction of Wetland Cells**

4.4.3.5 Ammoniacal Nitrogen (AN)

The mean AN for UN, CW and PL recorded after construction of wetland cells was 0.3 ± 0.2 mg $L^{-1}$, 0.3 ± 0.1 mg $L^{-1}$, 0.3 ± 0.3 mg $L^{-1}$ respectively (Table 30). The AN for UN ranged from 0.1 to 2.3 mg $L^{-1}$ with the minimum recorded in December 1999, March and April 2000 and November 1999. The maximum AN of 2.3 mg $L^{-1}$ was recorded in July 2000. In CW and PL, the AN ranged from 0.1 to 0.8 mg $L^{-1}$ and 0.1 to 2.4 mg $L^{-1}$ respectively. The minimum AN was recorded in November and December 1999, February and May 2000 for CW and the maximum was recorded in October 1999. In PL, the minimum mean AN was recorded in most of the months after construction of wetland cells except for the month of October 1999, January 2000 April and July 2000. The maximum AN was recorded in December 1999. The trend of AN is shown in

Figure 59. The mean AN showed fluctuation for this phase with high peaks recorded in October 1999 followed by a`sharp decline in November 1999 for UN and PL. The values go up again in December 1999 and decline gradually (with minor changes) after that. The third peak was indicated in July 2000 for mean AN in UN.

**Table 30. AN Values (mg $L^{-1}$) After Construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| Oct '99 | 0.3 | 0.7 | 0.5 (0.2) | 0.5 | 0.8 | 0.6 (0.1) | 0.4 | 0.6 | 0.5 (0.1) |
| Nov '99 | 0.2 | 0.4 | 0.3 (0.1) | 0.1 | 0.2 | 0.1 (0.0) | 0.1 | 0.1 | 0.1 (0.0) |
| Dec '99 | 0.1 | 0.6 | 0.2 (0.2) | 0.1 | 1.6 | 0.5 (0.7) | 0.1 | 2.4 | 0.4 (0.7) |
| Jan '00 | 0.2 | 0.7 | 0.3 (0.2) | 0.3 | 0.4 | 0.4 (0.1) | 0.2 | 0.5 | 0.3 (0.1) |
| Feb '00 | 0.2 | 0.6 | 0.3 (0.1) | 0.1 | 0.3 | 0.2 (0.1) | 0.1 | 0.5 | 0.3 (0.1) |
| Mac '00 | 0.1 | 0.9 | 0.3 (0.3) | 0.2 | 0.2 | 0.2 (0.0) | 0.1 | 1.7 | 0.3 (0.5) |
| Apr '00 | 0.1 | 0.4 | 0.2 (0.1) | 0.2 | 0.2 | 0.2 (0.0) | 0.2 | 1.4 | 0.3 (0.4) |
| May '00 | 0.2 | 0.4 | 0.3 (0.1) | 0.1 | 0.3 | 0.2 (0.1) | 0.1 | 2.1 | 0.4 (0.6) |
| June '00 | 0.2 | 1.2 | 0.4 (0.4) | 0.2 | 0.3 | 0.2 (0.1) | 0.1 | 0.6 | 0.2 (0.1) |
| July '00 | 0.2 | 2.3 | 0.6 (0.7) | 0.3 | 0.5 | 0.3 (0.1) | 0.2 | 0.4 | 0.3 (0.1) |
| Mean | | | 0.3 (0.2) | | | 0.3 (0.1) | | | 0.3 (0.3) |

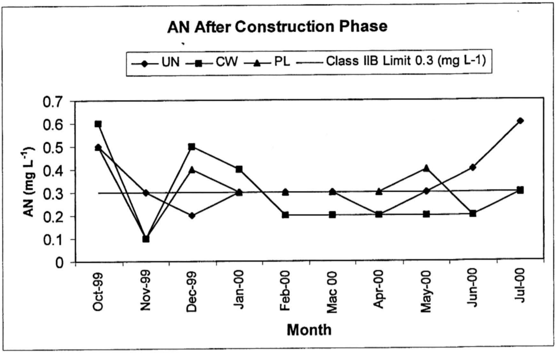


**Figure 59. AN Values (mg $L^{-1}$) After Construction of Wetland Cells**

4.4.3.6 Total Suspended Solids (TSS)

The mean TSS for UN, CW and PL is shown in Table 31. Mean TSS for UN was 21.1 ± 11.6 mg $L^{-1}$ with a range from 4.0 to 103.0 mg $L^{-1}$. The lowest TSS for UN was recorded in January and April 2000 and the highest TSS was recorded in November 1999. Mean TSS for CW was 9.2 ± 3.5 mg $L^{-1}$ with a range from 4.0 (December 1999, February, March, May and July 2000) to 27.0 mg $L^{-1}$ (February 2000). Mean TSS for PL was 8.2 ± 3.9 mg $L^{-1}$ with a range from 4.0 to 43.0 mg $L^{-1}$. The lowest TSS for PL was recorded in December 1999, January, March to June 2000 and the highest TSS was recorded in January 2000. Based on the Figure 60, the trend of mean TSS after construction of wetland cells fluctuated well within the Class IIB limit of 25 mg $L^{-1}$ with a peak recorded in November 1999 in UN.

**Table 31. TSS Values (mg L$^{-1}$) After Construction of Wetland Cells**

| Month | UN | | | CW | | | PL | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| Oct '99 | 12.0 | 30.0 | 17.8 (7.0) | 6.0 | 7.0 | 6.3 (0.5) | 7.0 | 8.0 | 7.3 (0.5) |
| Nov '99 | 23.0 | 103.0 | 45.8 (25.5) | 11.0 | 15.0 | 13.3 (1.7) | 10.0 | 17.0 | 12.5 (3.1) |
| Dec '99 | 5.0 | 26.0 | 9.9 (7.1) | 4.0 | 20.0 | 8.0 (8.0) | 4.0 | 12.0 | 5.4 (2.8) |
| Jan '00 | 4.0 | 63.0 | 19.3 (19.8) | 9.0 | 12.0 | 11.0 (1.4) | 4.0 | 43.0 | 10.8 (13.7) |
| Feb '00 | 9.0 | 38.0 | 17.1 (9.1) | 4.0 | 27.0 | 12.8 (10.0) | 6.0 | 16.0 | 9.3 (2.9) |
| Mac '00 | 14.0 | 29.0 | 19.4 (5.0) | 4.0 | 9.0 | 6.0 (2.2) | 4.0 | 23.0 | 7.0 (5.7) |
| Apr '00 | 4.0 | 30.0 | 15.6 (9.2) | 6.0 | 8.0 | 6.5 (1.0) | 4.0 | 10.0 | 5.5 (2.1) |
| May '00 | 13.0 | 33.0 | 23.4 (6.0) | 4.0 | 15.0 | 6.8 (5.5) | 4.0 | 8.0 | 4.8 (1.5) |
| June '00 | 5.0 | 44.0 | 16.5 (12.8) | 11.0 | 14.0 | 12.3 (1.3) | 4.0 | 15.0 | 8.8 (3.8) |
| July '00 | 9.0 | 47.0 | 25.8 (14.5) | 4.0 | 11.0 | 8.5 (3.1) | 7.0 | 17.0 | 10.8 (3.1) |
| Mean | | | 21.1 (11.6) | | | 9.2 (3.5) | | | 8.2 (3.9) |

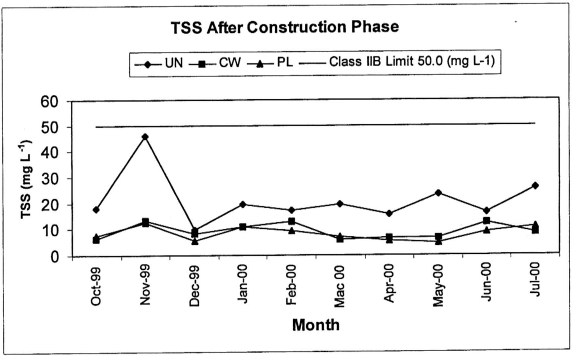


**Figure 60. TSS Values (mg L$^{-1}$) After Construction of Wetland Cells**

## 4.5 Meteorological Data

Meteorological data was obtained from the Malaysian Meteorological Service (MMS) from March 1997 to July 2000. The meteorological data obtained include the rainfall, temperature, solar radiation and cloud. All the data were obtained from the nearest meteorological stations at the Sultan Abdul Aziz Shah Airport at Subang, Selangor.

The study area exhibited a typical humid tropical climate with uniform high temperature, humidity and rainfall. The study area was influenced by both the Southwest and Northeast Monsoons. The moisture laden South-westerly winds prevail from May to September, followed by an inter-monsoonal period until early November. During November to March, the northeast monsoon sets in and is followed by another inter-monsoonal period until early May.

### 4.5.1 Rainfall

The average monthly rainfall from March 1997 to July 2000 recorded was 216.13 mm. The highest rainfall was recorded in November 1997 at 442.7 mm and the lowest in June 1999 at 24.8 mm.

### 4.5.2 Temperature

The overall temperature changes were quite constant. The mean monthly temperature from March 1997 to July 2000 ranged from 27.9°C. The highest temperature was recorded in April 1998 at 29.7°C and the lowest in December 1998 and January 1999 at 26.9°C.

### 4.5.3 Solar Radiation

The highest radiation was recorded in February 1998 at 19.53 MJ $m^{-2}$ and the lowest in September 1997 at 12.54 MJ $m^{-2}$. The mean monthly radiation obtained from March 1997 to July 2000 was at 16.45 MJ $m^{-2}$.

### 4.5.4 Cloud

The cloud cover recorded was constant from March 1997 to July 2000, which ranged from 6.8 oktas to 7 oktas. The mean cloud cover obtained was at 6.95 oktas.

Figure 61 shows the trend of meteorological data obtained from MMS from March 1997 to July 2000.

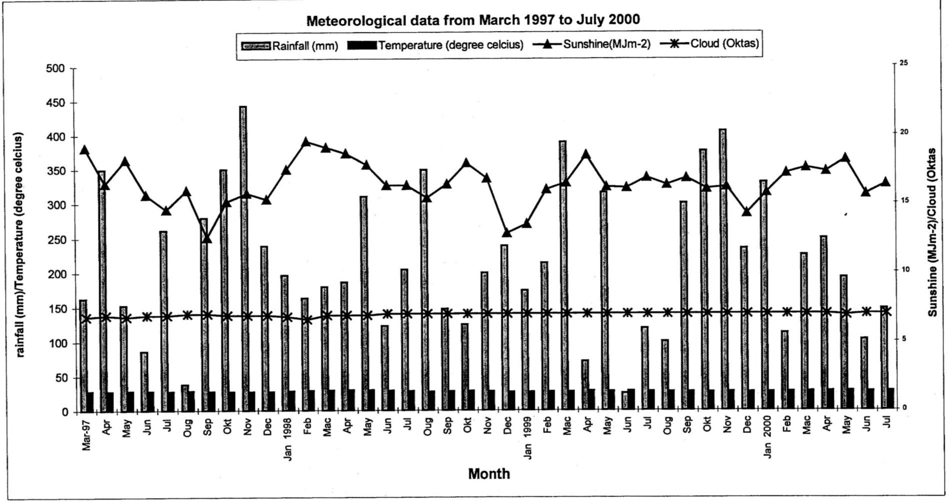


Figure 61. Meteorological Data from March 1997 to July 2000

### 4.6 Statistical Analysis

### 4.6.1 Simple Correlation between WQI with Water Quality Parameters and Meteorological Data

Simple correlation analysis using Spearman Rank Order Correlations were used to assess the association between WQI with water quality parameters and meteorological data over the study period and included all data from the three sites with meteorological data. Table 32 shows the results of correlation analysis with the significant values presented.

**Table 32. Correlation between WQI with Water Quality Parameters and Meteorological Data (Significant at $P < 0.05$).**

| Parameters | Spearman R | p-level |
|---|---|---|
| pH | -0.21 | < 0.05 |
| DO | 0.41 | < 0.05 |
| BOD | -0.46 | < 0.05 |
| COD | -0.41 | < 0.05 |
| AN | -0.73 | < 0.05 |
| TSS | 0.71 | < 0.05 |
| Rainfall | 0.03 | < 0.05 |
| Air temperature | -0.17 | < 0.05 |
| Sunshine | 0.12 | < 0.05 |
| Cloud | 0.40 | < 0.05 |

Results of simple correlation show that WQI are positively correlated with DO, rainfall, sunshine and cloud. On the other hand, WQI are influenced by pH, BOD, COD, AN and air temperature.

### 4.6.2 Simple Correlation among Water Quality Parameter with Meteorological Data

Simple correlation analysis using Spearman Rank Order Correlations was used to assess the association between each of the water quality parameters over the study period and included all data from the three sites with meteorological data. Table 33 shows the results of correlation analysis and the correlation values marked with an asterisk are significant at $p < 0.05$. The results in Table 33 shows that a low significant positive correlation existed between pH with DO ($r = 0.19$); BOD ($r = 0.19$); COD ($r = 0.09$); AN ($r = 0.26$) and TSS ($r = 0.36$). In addition, the pH has significantly low positive correlation with temperature ($r = 0.27$) and sunshine ($r = 0.37$). No significant correlation was observed between pH with rainfall and sunshine.

For DO, it is negatively correlated with BOD ($r = -0.12$) and COD ($r = -0.15$). DO has no significant correlation with AN and TSS. However, it has low positive significant correlation with temperature and sunshine with $r = 0.13$ and $r = 0.18$ respectively. BOD has low significant correlation with COD ($r = 0.48$); AN ($r = 0.30$); TSS ($r = 0.32$); sunshine ($r = 0.14$) and cloud ($r = 0.21$). However, no correlation was observed between BOD with rainfall and temperature. There is low significant positive correlation between COD with AN and TSS with $r = 0.09$ and $r = 0.14$ respectively. COD has no significant correlation with most of the meteorological data except for rainfall where they are negatively correlated with $r = - 0.11$.

A significant positive correlation is observed between AN with TSS (r = 0.60) and temperature (r = 0.25). However, AN is negatively correlated with cloud (r = -0.42).

As for TSS, it is observed to have positive correlation with most of the water quality parameters analysed except for DO (r = -0.06). On the other hand, TSS is positively correlated with temperature (r = 0.28) and negatively correlated with cloud (r = -0.47).

**Table 33. Correlation between Water Quality Parameters with Meteorological Data (Significant at P < 0.05)**

| Parameters | Water Quality Parameters | | | | | |
|---|---|---|---|---|---|---|
| | pH | DO | BOD | COD | AN | TSS |
| pH | | *0.19 | *0.19 | *0.09 | *0.26 | *0.36 |
| DO | *0.19 | | *-0.12 | *-0.15 | -0.05 | -0.06 |
| BOD | *0.19 | *-0.12 | | *0.48 | *0.30 | *0.32 |
| COD | *0.09 | *-0.15 | *0.48 | | *0.09 | *0.14 |
| AN | *0.26 | -0.05 | *0.30 | *0.09 | | *0.60 |
| TSS | *0.36 | -0.06 | *0.32 | *0.14 | *0.60 | |
| Rainfall | 0.04 | 0.02 | -0.02 | *-0.11 | -0.04 | -0.02 |
| Temperature | *0.27 | *0.13 | 0.04 | -0.00 | *0.25 | *0.28 |
| Sunshine | -0.01 | *0.18 | *-0.14 | -0.06 | -0.02 | -0.03 |
| Cloud | *-0.37 | -0.04 | *-0.21 | -0.07 | *-0.42 | *-0.47 |

### 4.6.3 Analysis of Variance (ANOVA)

ANOVA followed by multiple range test (Newman Keul test) was used to compare differences in water quality parameters among the phases, wetland cells (locations) and season (wet and dry) (3-factor/3-way ANOVA). As the monthly rainfall data obtained from March 1997 to July 2000 fluctuated greatly throughout the year and no distinctive trend were observed, the wet and dry season was determined by using the mean monthly rainfall data from 1966 – 2000 of Sultan Abdul Aziz Shah Airport at Subang, which was obtained from MMS. Table 34 below shows the trend of mean monthly rainfall data from 1966 to 2000.

**Table 34. Mean Rainfall Data from 1966 – 2000 from Malaysia Meteorological Services (MMS)**

| Month | Mean Rainfall (mm) | Trend of seasons |
|---|---|---|
| January | 179 | Dry |
| February | 159 | |
| March | 239 | Wet |
| April | 274 | |
| May | 204 | |
| June | 130 | Dry |
| July | 126 | |
| August | 153 | |
| September | 189 | |
| October | 258 | Wet |
| November | 279 | |
| December | 246 | |

(Source: MMS)

**WQI in relation to phases (pre-construction, during construction and after construction), locations (UN, CW and PL) and seasons (wet and dry)**

The ANOVA results showed that WQI was significantly different only within phase ($p < 0.05$) (Table 35; Appendix 3.1). No significant difference of WQI was observed between locations, seasons and any interaction between and among the three factors. Based on the Newman Keuls test, there was significant difference of WQI between pre-construction and during construction of wetland cells and between pre-construction and after construction of wetland cells. WQI obtained during construction of wetland cells was not significantly different with WQI after construction of wetland cells (Appendix 3.1).

The mean WQI for the three locations (UN, CW and PL) in phase 1 was significantly lower than phases 2 and 3 (Figure 62). The mean WQI was lower in dry season compared with wet season for pre-construction of wetland cells (Figure 63). However, mean WQI was lower for the three sites during construction of wetland cells compared with mean WQI after construction of wetland cells. Mean WQI after the construction of wetland cells (when the condition of wetlands was stable) was high during wet season compared with dry season (Figure 63).

**Table 35. Analysis of Variance (ANOVA) in WQI as Influenced by Phases, Locations and Seasons**

| STAT GENERAL MANOVA | Summary of all Effects; design: (anova2.sta) 1-PHASE, 2-LOCATION, 3-SEASON | | | | | |
|---|---|---|---|---|---|---|
| Effect | df Effect | MS Effect | df Effect | MS Error | F | p-level |
| 1 | 2* | 0.158804* | 557* | 0.013958* | 11.37729* | 0.000014* |
| 2 | 2 | 0.020440 | 557 | 0.013958 | 1.46440 | 0.232106 |
| 3 | 1 | 0.029776 | 557 | 0.013958 | 2.13322 | 0.144701 |
| 12 | 4 | 0.004280 | 557 | 0.013958 | 0.30661 | 0.873587 |
| 13 | 2 | 0.018752 | 557 | 0.013958 | 1.34343 | 0.261793 |
| 23 | 2 | 0.000398 | 557 | 0.013958 | 0.02848 | 0.971921 |
| 123 | 4 | 0.001465 | 557 | 0.013958 | 0.10499 | 0.980759 |

* = Significant

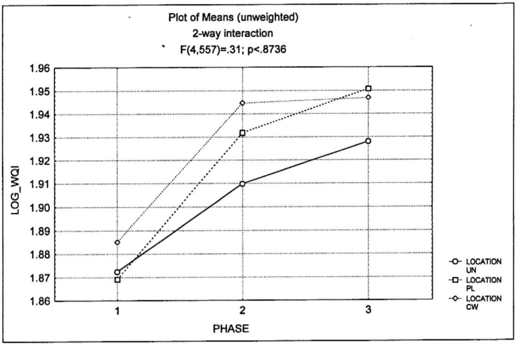


**Figure 62. Mean WQI of UN, CW and PL for phase 1 (pre-construction), 2 (during construction) and 3 (after construction)**

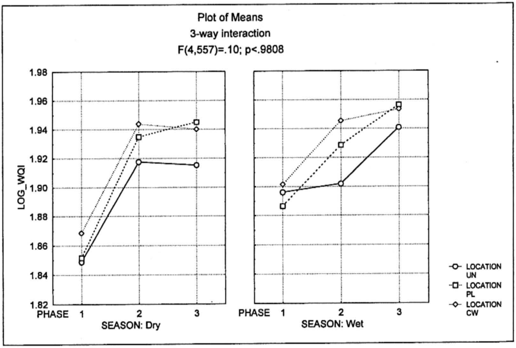


**Figure 63. Mean WQI as Influenced by Phases (1 = pre-construction*; 2 = during construction*; 3 = after construction), Locations (UN*CW*PL) and Seasons (wet*dry)**

**pH in relation to phases (pre-construction, during construction and after construction), locations (UN, CW and PL) and seasons (wet and dry)**

The 3-factor ANOVA results show that pH exhibit significant temporal and spatial differences (Table 36) (Appendix 3.2 and 3.3). No significant difference of pH with season was observed (Appendix 3.4). Significant temporal differences were showed between pre-construction phase with during construction phase and as well as after construction phase (Appendix 3.2). pH were significantly different between UN and PL ($P < 0.005$) and CW and PL ($P < 0.05$). No significant difference of pH between UN and CW ($p > 0.05$) was observed (Appendix 3.3). There were significant interaction effects between location (wetland cells) and phases, seasons and phases. By using the Newman-Keuls test as Post Hoc test, pH in UN, CW and PL was significantly different among pre-construction, during construction and after construction phase ($p < 0.05$) (Appendix 3.5). However, interaction effects between phases, locations and seasons showed no significant difference ($p > 0.05$) (Table 35).

The mean pH for the three locations (UN, CW and PL) in phase 1 (pre-construction of wetland cells) was significantly higher than phase 2 (during construction of wetland cells) and phase 3 (after construction of wetland cells) (Figure 64; Appendix 3.2) for wet and dry season (Figure 65; Appendix 3.6).

**Table 36. Analysis of Variance (ANOVA) in pH as Influenced by Phases, Locations and Seasons**

| STAT GENERAL MANOVA | Summary of all Effects; design: (anova2.sta) 1-PHASE, 2-LOCATION, 3-SEASON | | | | | |
|---|---|---|---|---|---|---|
| Effect | df Effect | MS Effect | df Effect | MS Error | F | p-level |
| 1 | 2* | 0.105175* | 557* | 0.000634* | 165.9590* | 0.000000* |
| 2 | 2* | 0.005509* | 557* | 0.000634* | 8.6924* | 0.000192* |
| 3 | 1 | 0.000672 | 557 | 0.000634 | 1.0603 | 0.303602 |
| 12 | 4* | 0.005616* | 557* | 0.000634* | 8.8614* | 0.000001* |
| 13 | 2* | 0.004822* | 557* | 0.000634* | 7.6081* | 0.000550* |
| 23 | 2 | 0.001633 | 557 | 0.000634 | 2.5769 | 0.076916 |
| 123 | 4 | 0.000280 | 557 | 0.000634 | 0.4424 | 0.777995 |

* = Significant

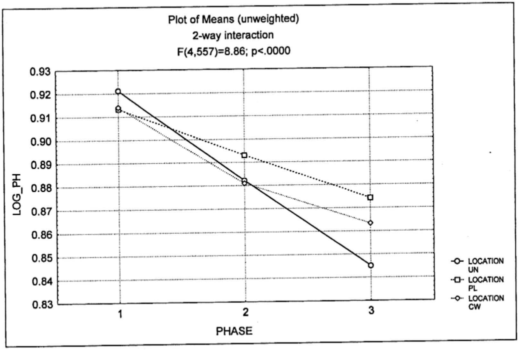


**Figure 64. Mean pH of UN, CW and PL for Phase 1 (pre-construction), 2 (during construction) and 3 (after construction)**

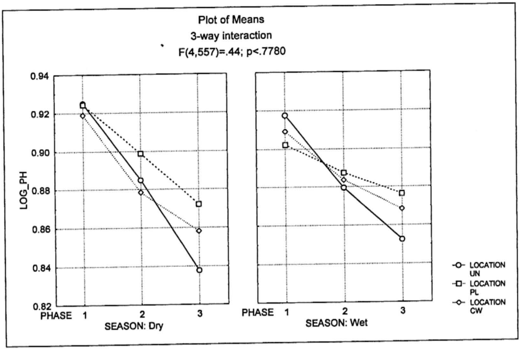


**Figure 65. Mean pH as Influenced by Phases (1 = pre-construction*; 2 = during construction*; 3 = after construction), Locations (UN*CW*PL) and Seasons (wet*dry)**

**DO in relation to phases (pre-construction, during construction and after construction), locations (UN, CW and PL) and seasons (wet and dry)**

The ANOVA results show that DO was significantly different within phase, location and season (Table 37; Appendix 3.8 – 3.10). DO also showed significant difference effects on the interaction between phase and location, phase and season and location and season ($p < 0.05$). However, no significant difference between phases, locations and seasons was observed. DO in UN showed significant difference ($p < 0.05$) between pre-construction and during construction phase. However, no significant difference between DO in pre-construction and after construction phase ($p > 0.05$) was observed. DO in PL showed no significant difference between both pre-construction and during construction phase ($p > 0.05$) and during construction and after construction phase. However, DO in

CW showed significant difference between pre-construction and after construction phase ($p < 0.05$). DO in CW showed no significant difference between the three phases. As for interaction effects between phases and seasons, DO was significantly different in pre-construction phase in different season (Appendix 3.11). This was similar for the DO after construction phase. There was significant difference between DO after construction phase in different seasons (Appendix 3.12).

The mean DO for the three locations (UN, CW and PL) in phase 1 was significantly lower than phase 2 and 3 (Figure 66; Appendix 3.11). The mean DO was lower in the dry season compared with wet season for the three sites in pre-construction and after construction phase (Figure 67). During construction, the mean DO was not significantly different (Appendix 3.12). The mean DO was significantly different in UN for both the dry and wet seasons ($p < 0.05$). Both PL and CW do not exhibit significant differences of DO for the wet and dry seasons ($p > 0.05$) (Appendix 3.13).

**Table 37. Analysis of Variance (ANOVA) in DO as Influenced by Phases, Locations and Seasons**

| STAT GENERAL MANOVA | Summary of all Effects; design: (anova2.sta) 1-PHASE, 2-LOCATION, 3-SEASON | | | | | |
|---|---|---|---|---|---|---|
| Effect | df Effect | MS Effect | df Effect | MS Error | F | p-level |
| 1 | 2* | 0.017998 | 557* | 0.002356* | 7.63891* | 0.000534* |
| 2 | 2* | 0.041181* | 557* | 0.002356* | 17.47842* | 0.000000* |
| 3 | 1* | 0.053911* | 557* | 0.002356* | 22.88167* | 0.000002* |
| 12 | 4* | 0.008376* | 557* | 0.002356* | 3.55495* | 0.007086* |
| 13 | 2* | 0.029777* | 557* | 0.002356* | 12.63851* | 0.000004* |
| 23 | 2* | 0.008137* | 557* | 0.002356* | 3.45380* | 0.032304* |
| 123 | 4 | 0.005447 | 557 | 0.002356 | 2.31194 | 0.056562 |

* = Significant

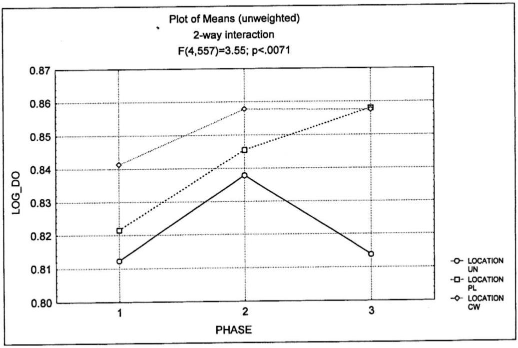


**Figure 66. Mean DO of UN, CW and PL for Phase 1 (pre-construction), 2 (during construction) and 3 (after construction)**

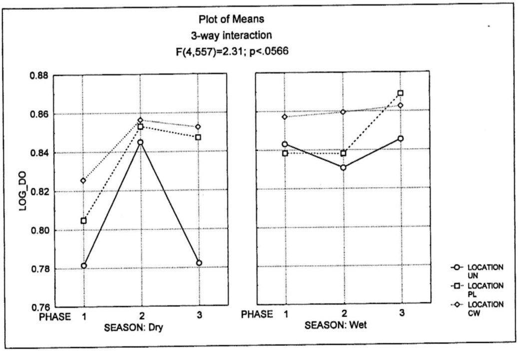


**Figure 67. Mean DO as Influenced by Phases (1 = pre-construction*; 2 = during construction*; 3 = after construction), Locations (UN*CW*PL) and Seasons (wet*dry)**

**BOD in relation to phases (pre-construction, during construction and after construction), locations (UN, CW and PL) and seasons (wet and dry)**

Based on the results of ANOVA (Table 38), BOD was significantly different within phase and season (Appendix 3.14 – 3.16). Mean BOD showed significant interaction effects between phase and season ($p < 0.05$) (Appendix 3.18). Interaction effects between phases and locations and between locations and seasons were not significant ($p > 0.05$) (Table 37; Appendix 3.19). Significant temporal differences for mean BOD were shown within the three phases between pre-construction and during construction phase, between pre-construction and after construction phase and between during construction and after construction phase ($p < 0.05$) (Appendix 3.14; Figure 68). The mean BOD was significantly higher in pre-construction phase than during and after construction phase. No significant spatial differences were observed for BOD ($p > 0.05$) (Appendix 3.15). However, BOD was significantly differences between dry and wet seasons ($p < 0.05$) (Appendix 3.16).

BOD in UN, CW and PL showed significant difference between pre-construction and during construction phase ($p < 0.05$) and between pre-construction and after construction phase ($p < 0.05$). Interaction effect between during construction and after construction phases for UN, CW and PL was not significant ($p > 0.05$) (Appendix 3.17). As for interaction effects between phases and seasons, BOD was significantly different between wet and dry seasons in pre-construction and during construction phase. There was no significant difference between wet and dry seasons after construction phase (Appendix 3.18; Figure 69).

The mean BOD for the three locations (UN, CW and PL) in phase 1 (pre-construction phase) was significantly higher than phase 2 (during construction) and 3 (after construction) (Figure 68; Appendix 3.17). The mean BOD was higher in dry season compared with wet season for the three sites in pre-construction and during construction phase (Appendix 3.18; Figure 69). The mean BOD was not significantly different after construction phase (Appendix 3.18). The mean BOD was not significantly different at the three sites for both the dry and wet seasons ($p > 0.05$) (Appendix 3.19).

**Table 38. Analysis of Variance (ANOVA) in BOD as Influenced by Phases, Locations and Seasons**

| STAT GENERAL MANOVA | Summary of all Effects; design: (anova2.sta) 1-PHASE, 2-LOCATION, 3-SEASON | | | | | |
|---|---|---|---|---|---|---|
| Effect | df Effect | MS Effect | df Effect | MS Error | F | p-level |
| 1 | 2* | 1.120260* | 557* | 0.012810* | 87.45000* | 0.000000* |
| 2 | 2 | 0.006417 | 557 | 0.012810 | 0.50093 | 0.606237 |
| 3 | 1* | 0.099985* | 557* | 0.012810* | 7.80505* | 0.005389* |
| 12 | 4 | 0.014927 | 557 | 0.012810 | 1.16521 | 0.325158 |
| 13 | 2* | 0.336254* | 557* | 0.012810* | 26.24870* | 0.000000* |
| 23 | 2 | 0.008762 | 557 | 0.012810 | 0.68396 | 0.505039 |
| 123 | 4 | 0.014878 | 557 | 0.012810 | 1.16141 | 0.326877 |

* = Significant

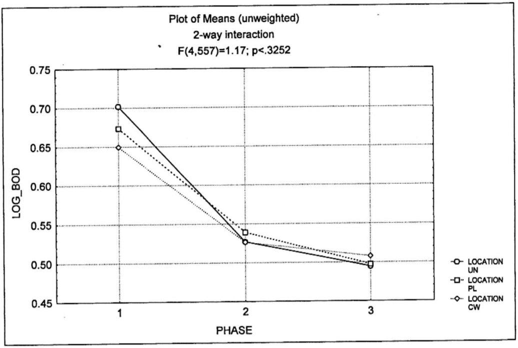


**Figure 68. Mean BOD of UN, CW and PL for Phase 1 (pre-construction), 2 (during construction) and 3 (after construction)**

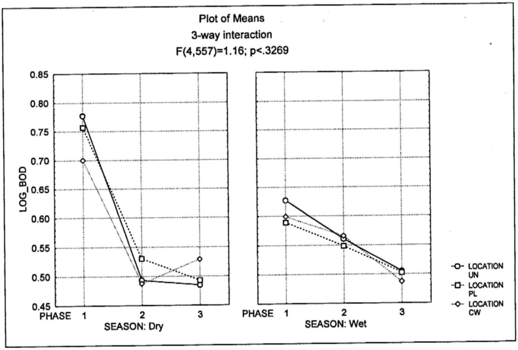


**Figure 69. Mean BOD as Influenced by Phases (pre-construction*during construction*after construction), Locations (UN*CW*PL) and Seasons (wet*dry)**

**COD in relation to phases (pre-construction, during construction and after construction), locations (UN, CW and PL) and seasons (wet and dry)**

Table 39 shows that COD was significantly different within phases and seasons (Appendix 3.20 – 3.22). Mean COD showed significant interaction effects between phase and season ($p = 0.02$). Interaction effects between phases and locations and between locations and seasons were not significant ($p > 0.05$) (Table 39). Temporal differences were significant in the three phases between pre-construction and during construction phase, between pre-construction and after construction phase and between during construction and after construction phase ($p < 0.05$) (Appendix 3.20; Figure 70). The mean COD was significantly higher in pre-construction phase than during and after construction phase. Spatial differences were not significant for COD ($p > 0.05$) (Appendix 3.21). However, COD was significantly differences between dry and wet seasons ($p < 0.05$) (Appendix 3.22).

COD in UN, CW and PL showed significant difference between pre-construction and after construction phase ($p < 0.05$) (Appendix 3.23). COD was not significantly different between pre-construction and during construction phase ($p > 0.05$) and during construction and after construction phase ($p > 0.05$) (Appendix 3.23). COD exhibited significant differences between wet and dry seasons in pre-construction and after construction phase. There was no significant difference between wet and dry seasons during construction phase (Appendix 3.24; Figure 71).

The mean COD for the three locations (UN, CW and PL) in phase 1 (pre-construction phase) was significantly higher than phase 2 (during construction) and 3 (after construction) (Figure 70). The mean COD was higher in dry season compared with wet season for the three sites in pre-construction and after construction phase (Appendix 3.24; Figure 71). The mean COD was not significantly different during construction phase (Appendix 4.17) for the wet and dry seasons. The mean COD was significantly different between the dry and wet seasons in UN and CW ($p < 0.05$) (Appendix 3.25). However, no significant difference of means COD between dry and wet seasons in PL ($p > 0.05$) (Appendix 3.25).

**Table 39. Analysis of Variance (ANOVA) in COD as Influenced by Phases, Locations and Seasons**

| STAT GENERAL MANOVA | Summary of all Effects; design: (anova2.sta) 1-PHASE, 2-LOCATION, 3-SEASON | | | | | |
|---|---|---|---|---|---|---|
| Effect | df Effect | MS Effect | df Effect | MS Error | F | p-level |
| 1 | 2* | 1.522030* | 557* | 0.105703* | 14.39909* | 0.000001* |
| 2 | 2 | 0.009631 | 557 | 0.105703 | 0.09111 | 0.912930 |
| 3 | 1* | 1.805554* | 557* | 0.105703* | 17.08136* | 0.000041* |
| 12 | 4 | 0.005157 | 557 | 0.105703 | 0.04878 | 0.995525 |
| 13 | 2* | 0.413368* | 557* | 0.105703* | 3.91065* | 0.020580* |
| 23 | 2 | 0.011767 | 557 | 0.105703 | 0.11132 | 0.894675 |
| 123 | 4 | 0.018468 | 557 | 0.105703 | 0.17472 | 0.951367 |

* = Significant

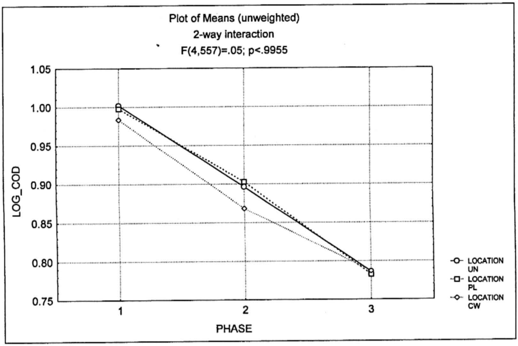


**Figure 70. Mean COD of UN, CW and PL for Phase 1 (pre-construction), 2 (during construction) and 3 (after construction)**

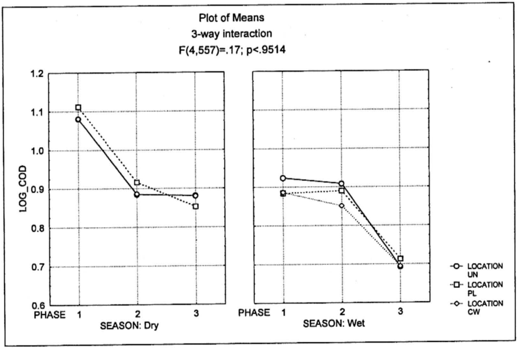


**Figure 71. Mean COD as Influenced by Phases (pre-construction*during construction*after construction), Locations (UN*CW*PL) and Seasons (wet*dry)**

**AN in relation to phases (pre-construction, during construction and after construction), locations (UN, CW and PL) and seasons (wet and dry)**

The ANOVA results show that mean AN was significantly different within phases, locations and seasons ($p < 0.05$) (Appendix 3.26– 3.28). Mean AN was significantly different between pre-construction and during construction phase ($p < 0.05$) and between pre-construction and after construction phase ($p < 0.05$) (Appendix 3.26). Significant spatial differences were shown between UN and PL and between UN and CW ($p < 0.05$) (Appendix 3.27). No significant difference between CW and PL ($p > 0.05$) (Appendix 3.27). Significant differences were shown between mean AN in dry and wet seasons ($p < 0.05$) (Appendix 3.28). Interaction effects for mean AN was significant between phases and seasons and between location and seasons ($p < 0.05$) (Table 40). However, mean AN was not significantly interacted between phases, locations and seasons (Table 40).

Overall, no significant difference for mean AN between phases and locations ($p > 0.05$) was observed. Mean AN was significantly different in UN, PL and CW between pre-construction and during construction phase and between pre-construction and after construction phase ($p < 0.05$) (Appendix 3.29). However, no significant differences ($p > 0.05$) between during construction and after construction phase for mean AN at the three sites was observed (Figure 72). There were significant interaction effects for mean AN between pre-construction phase and both the dry and wet seasons ($p < 0.05$) (Appendix 3.30; Figure 73). No significant interaction effects between mean AN during construction and after construction phase ($p > 0.05$) (Appendix 3.30; Figure 73).

As for interaction effects between locations and seasons, mean AN in UN and CW was significantly different between the dry and wet seasons (Appendix 3.31). However, no significant difference was shown in PL between dry and wet seasons ($p > 0.05$) (Appendix 3.31).

The mean AN for the three locations (UN, CW and PL) in phase 1 (pre-construction phase) was significantly higher than phase 2 (during construction) and 3 (after construction) (Figure 72). The mean AN was lower in wet season compared with dry season for the three sites in pre-construction phase (Figure 73). Mean AN was not significantly different during construction phase for the three sites (Appendix 3.29; Figure 73).

**Table 40. Analysis of Variance (ANOVA) in AN as Influenced by Phases, Locations and Seasons**

| STAT GENERAL MANOVA | Summary of all Effects; design: (anova2.sta) 1-PHASE, 2-LOCATION, 3-SEASON | | | | | |
|---|---|---|---|---|---|---|
| Effect | df Effect | MS Effect | df Effect | MS Error | F | p-level |
| 1 | 2* | 1.375483* | 557* | 0.006974* | 197.2309* | 0.000000* |
| 2 | 2* | 0.035658* | 557* | 0.006974* | 5.1130* | 0.006303* |
| 3 | 1* | 0.182862* | 557* | 0.006974* | 26.2206* | 0.000000* |
| 12 | 4 | 0.015570 | 557 | 0.006974 | 2.2326 | 0.064287 |
| 13 | 2* | 0.172842* | 557* | 0.006974* | 24.7839* | 0.000000* |
| 23 | 2* | 0.050480* | 557* | 0.006974* | 7.2384* | 0.000788* |
| 123 | 4 | 0.002799 | 557 | 0.006974 | 0.4013 | 0.807765 |

* = Significant

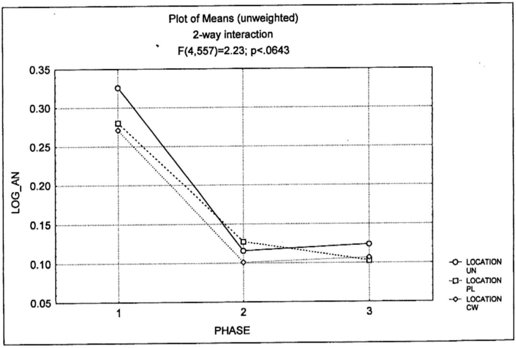


**Figure 72. Mean AN of UN, CW and PL for Phase 1 (pre-construction), 2 (during construction) and 3 (after construction)**

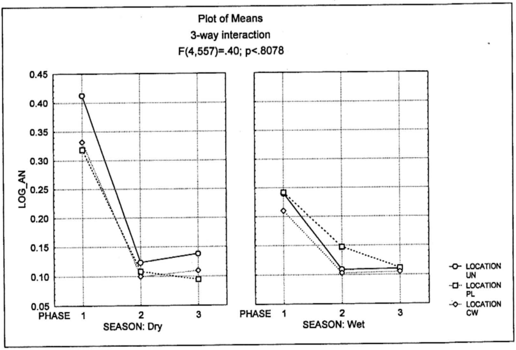


**Figure 73. Mean AN as influenced by Phases (pre-construction*during construction*after construction), Locations (UN*CW*PL) and Seasons (wet*dry)**

**TSS in relation to phases (pre-construction, during construction and after construction), locations (UN, CW and PL) and seasons (wet and dry)**

Table 40 shows the results of ANOVA for TSS. From the results obtained, TSS exhibited significantly temporal differences within phases ($p < 0.05$) (Appendix 3.32). TSS was significant between pre-construction and during construction phase, pre-construction and after construction phase and also during construction and after construction phase ($p < 0.05$) (Appendix 3.32). However, ANOVA analysis showed no significant difference for mean TSS with locations and seasons (Appendix 3.33 & 3.34). Interaction effect between phases and locations was significant at $p < 0.05$ (Appendix 3.35). No significant interaction effect was obtained between phases and seasons ($p > 0.05$) (Appendix 3.36), locations and seasons ($p > 0.05$) (Appendix 3.37) and between phases, locations and seasons (Table 41).

Based on the Newman-Keuls test, TSS in UN showed significant difference ($p < 0.05$) between pre-construction and during construction phase and between pre-construction and after construction phase. However, no significant difference for TSS between during construction and after construction phase ($p > 0.05$). TSS in PL and CW showed significant interaction effects among the three phases ($p < 0.05$) (Appendix 3.35; Figure 74).

The mean TSS for the three locations (UN, CW and PL) in phase 1 was significantly higher than phase 2 and 3 (Figure 74; Table 40). The mean TSS was not significant between dry and wet season for the three sites among the three phases (Figure 75).

**Table 41. Analysis of Variance (ANOVA) in TSS as Influenced by Phases, Locations and Seasons**

| STAT GENERAL MANOVA | Summary of all Effects; design: (anova2.sta) 1-PHASE, 2-LOCATION, 3-SEASON | | | | | |
|---|---|---|---|---|---|---|
| Effect | df Effect | MS Effect | df Effect | MS Error | F | p-level |
| 1 | 2* | 41.58960* | 557* | 0.154033* | 270.0043* | 0.000000* |
| 2 | 2 | 0.02400 | 557 | 0.154033 | 0.1558 | 0.855779 |
| 3 | 1 | 0.20489 | 557 | 0.154033 | 1.3302 | 0.249265 |
| 12 | 4* | 2.37924* | 557* | 0.154033* | 15.4463* | 0.000000* |
| 13 | 2 | 0.11177 | 557 | 0.154033 | 0.7256 | 0.484476 |
| 23 | 2 | 0.25427 | 557 | 0.154033 | 1.6507 | 0.192848 |
| 123 | 4 | 0.08431 | 557 | 0.154033 | 0.5474 | 0.701032 |

* = Significant

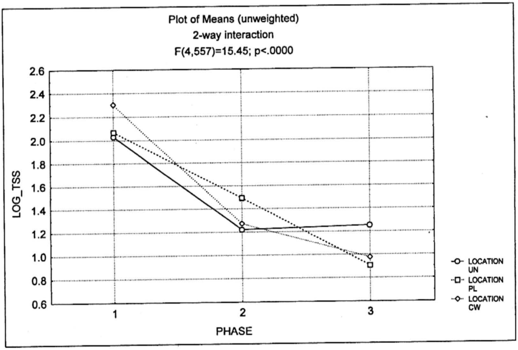


**Figure 74. Mean TSS of UN, CW and PL for Phase 1 (pre-construction), 2 (during construction) and 3 (after construction)**

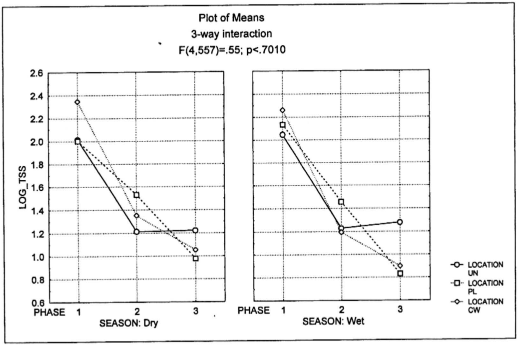


**Figure 75. Mean TSS as influenced by Phases (pre-construction*during construction*after construction), Locations (UN*CW*PL) and Seasons (wet*dry)**

### 4.6.4 Principal Components Analysis (PCA)

The PCA (a data reduction method) results are displayed in the form of biplots of water quality parameters and samples where water quality parameters are depicted by arrows and the samples are marked by points (Figure 76). Four factors or principal components (PC) were extracted. The first principal component (PC1) accounts for 80.64% of the total variance, while the second principal component (PC2) accounts for 15.92% and the first four principal components together accounted for 99.5% of the total variance. Therefore, it would be reasonable to summarize the data using the first four principal components. However, results on only the first two principal components as two-dimensional plots, are shown in Figure 76.

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The principal components with their respective computed linear combinations are as follows:

PC1 = 0.6642 log pH + 0.0407 log DO + 0.6027 log BOD + 0.3672 log COD + 0.7192 log AN + 1.0516 log TSS.

PC2 = -0.0032 log pH – 0.3272 log DO + 0.4885 log BOD + 1.4821 log COD + 0.1561 log AN – 0.1285 log TSS.

PC3 = 0.0123 log pH – 0.9840 log DO + 1.6919 log BOD – 0.1321 log COD + 1.5483 log AN – 0.0554 log TSS.

PC4 = - 0.2535 log pH – 1.1392 log DO – 1.3299 log BOD + 0.0336 log COD + 1.3396 log AN – 0.0066 log TSS.

Table 42 shows the variances of the four principal components (eigen-value) and their proportion to the total variance. Table 43 shows their respective coefficients or factor loadings for each variable. Factor loadings are the correlations between original variables and the principal components.

**Table 42. Variances (eigenvalue) and Proportion to Total Variance for Each Principal Component**

| Factor analysis | PC1 | PC2 | PC3 | PC4 |
|---|---|---|---|---|
| Eigenvalues | 0.8064 | 0.1592 | 0.0201 | 0.0091 |
| % total variance | 80.6 | 15.92 | 2.01 | 0.91 |
| Cumulative Eigenvalues | 0.8064 | 0.9660 | 0.9860 | 0.995 |
| Cumulative percentage variance | 80.6 | 96.6 | 98.6 | 99.5 |

**Table 43. Extracted Principal Components and Respective Matrix of Coefficients**

| Variable | PC1 | PC2 | PC3 | PC4 |
|---|---|---|---|---|
| Log pH | 0.6642 | -0.0032 | 0.0123 | -0.2535 |
| Log DO | 0.0407 | -0.3272 | -0.984 | -1.1392 |
| Log BOD | 0.6027 | 0.4885 | 1.6979 | -1.3299 |
| Log COD | 0.3672 | 1.4821 | -0.1321 | 0.0336 |
| Log AN | 0.7192 | 0.1561 | 1.5483 | 1.3396 |
| Log TSS | 1.0516 | -0.1285 | -0.0554 | -0.0066 |

The loadings on PC1 showed the relatively higher contribution of pH (0.6642), BOD (0.6027) and TSS (1.0516) concentrations in the positive direction (at right side of the x-axis). For PC2, the loadings showed the relative importance of COD (1.4821) (positive direction of the y-axis). For PC3, the loadings showed the relative importance of BOD (1.6979) and AN (1.5483) concentrations in the positive direction of the third – axis (three dimensional). As for PC4, the relatively importance of high AN (1.3396) is shown in the positive direction of the fourth axis (three dimensional) and high DO (1.1392) and BOD (1.3299) in the negative direction of the fourth axis.

Figure 76 shows the biplots of both environmental factors and samples (sites) on PC1 (x-axis) and PC2 (y –axis). Environmental factors are depicted by arrow, the length of which indicates its relative loadings (strength) and direction the gradient of increasing magnitude. The origin (0,0) indicates the mean values of each variables. Samples taken from sites are depicted by 3 symbols corresponding to the 3 phases. Each sample is labeled with the number corresponding to the phase of sampling (1 = pre-construction of wetland cells; 2 = during construction of wetland cells; 3 = after construction of wetland cells), site and number of sampling points (UN 1 - 8, CW 1 - 4 and PL 1 - 10) and the seasons (dry and wet).

Generally, the points cluster into five main group: Groups A, B, C, D and E. Group A and B is observed on the positive side of x-axis. Samples from Group A had high pH, BOD, AN, TSS but low DO concentrations and most of them were from phase 1 (pre-construction of wetland cells). Most of the samples from Group A were collected during the dry season as compared to Group B. Samples from Group B which was collected during wet seasons also exhibited high pH, BOD, AN, TSS but high DO compared to Group A. Group C is clustered to the middle of the x-axis and y-axis. This group as compared to Group A and B posses relatively lower pH, BOD, AN and TSS concentrations but slightly higher COD concentrations. Most of the water samples collected during construction phase are clustered in this group. Group D and E are on the opposite side of Group A. This indicated that samples in Group D and E had lower pH, BOD, AN and TSS compared to group A and B. Group D showed high COD and lower DO concentrations compared to Group E. The water samples collected after construction phase during wet season are largely located on the extreme negative end of PC2 (i.e opposite direction of COD arrow). Therefore, these samples had lowest concentrations of COD and highest DO as compared to other samples collected. However, the water samples collected after construction phase during dry season are mainly located at the positive end of the y-axis of PC2 and thus the highest concentrations of COD. Most of the points indicated water samples collected from primary lake and central wetland after construction phase.

Table 44 shows the abbreviation of each of the water samples shown in Figure 76.

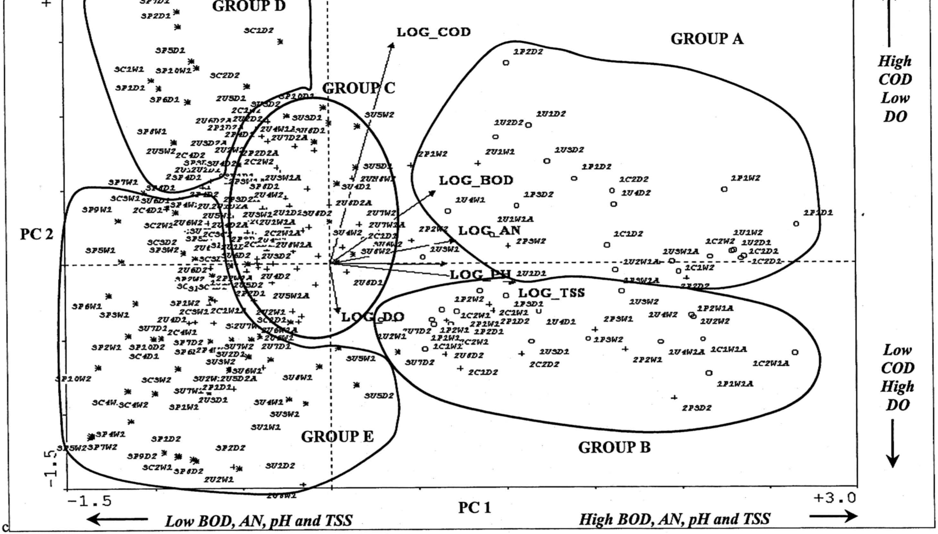


Figure 76. PCA Ordination Showing the Distribution of Water Quality Parameters (arrowed) in Relation to the Water Samples. (circles indicate water samples collected at pre-construction phase. + indicates water sample samples collected during construction phase and * indicated water samples collected after construction phase)

**Table 44. Abbreviation for PCA Plot**

| Phases | Locations | Seasons | Abbreviation |
|---|---|---|---|
| Pre-construction (March 1997 – April 1998) | UN (1-4) CW (1-2) PL (1-3) | Wet (March – May 1997) | 1U1W1, 1U2W1, 1U3W1, IU4W1, 1C1W1, 1C2W1, 1P1W1, 1P2W1, 1P3W1. |
| | | Dry (June – September 1997) | 1U1D2, 1U2D2, 1U3D2, IU4D2, 1C1D2, 1C2D2, 1P1D2, 1P2D2, 1P3D2. |
| | | Wet (October 1997 – December 1997) | 1U1W2, 1U2W2, 1U3W2, IU4W2, 1C1W2, 1C2W2, 1P1W2, 1P2W2, 1P3W2. |
| | | Dry (January – February 1998) | 1U1D1, 1U2D1, 1U3D1, IU4D1, 1C1D1, 1C2D1, 1P1D1, 1P2D1, 1P3D1. |
| | | Wet (March – April 1998) | 1U1W1A, 1U2W1A, 1U3W1A, IU4W1A, 1C1W1A, 1C2W1A, 1P1W1A, 1P2W1A, 1P3W1A. |
| During construction (May 1998 – September 1999) | UN (1-8) CW (1-4) PL (1-4) | Wet (May 1998) | 2U1W1, 2U2W1, 2U3W1, 2U4W1, 2U5W1, 2U6W1, 2U7W1, 2U8W1, 2C1W1, 2C2W1, 2C3W1, 2P1W1, 2P2W1, 2P3W1, 2P4W1. |
| | | Dry (June 1998 – September 1998) | 2U1D1, 2U2D1, 2U3D1, 2U4D1, 2U5D1, 2U6D1, 2U7D1, 2U8D1, 2C1D1, 2C2D1, 2C3D1, 2P1D1, 2P2D1, 2P3D1, 2P4D1. |
| | | Wet (October –December 1998) | 2U1W2, 2U2W2, 2U3W2, 2U4W2, 2U5W2, 2U6W2, 2U7W2, 2U8W2, 2C1W2, 2C2W2, 2C3W2, 2P1W2, 2P2W2, 2P3W2, 2P4W2. |
| | | Dry (January – February 1999) | 2U1D1A, 2U2D1A, 2U3D1A, 2U4D1A, 2U5D1A, 2U6D1A, 2U7D1A, 2U8D1A, 2C1D1A, 2C2D1A, 2C3D1A, 2P1D1A, 2P2D1A, 2P3D1A, 2P4D1A. |
| | | Wet (March – May 1999) | 2U1W1A, 2U2W1A, 2U3W1A, 2U4W1A, 2U5W1A, 2U6W1A, 2U7W1A, 2U8W1A, 2C1W1A, 2C2W1A, 2C3W1A, 2P1W1A, 2P2W1A, 2P3W1A, 2P4W1A. |
| | | Dry (June – September 1999) | 2U1D2A, 2U2D2A, 2U3D2A, 2U4D2A, 2U5D2A, 2U6D2A, 2U7D2A, 2U8D2A, 2C1D2A, 2C2D2A, 2C3D2A, 2P1D2A, 2P2D2A, 2P3D2A, 2P4D2A. |
| After construction (October 1999 – July 2000) | UN (1-8) CW (1-4) PL (1-10) | Wet (October –December 1999) | 3U1W2, 3U2W2, 3U3W2, 3U4W2, 3U5W2, 3U6W2, 3U7W2, 3U8W2, 3C1W2, 3C2W2, 3C3W2, 3P1W2, 3P2W2, 3P3W2, 3P4W2, 3P5W2, 3P6W2, 3P7W2, 3P8W2, 3P9W2, 3P10W2. |
| | | Dry (January – February 2000) | 3U1D1, 3U2D1, 3U3D1, 3U4D1, 3U5D1, 3U6D1, 3U7D1, 3U8D1, 3C1D1, 3C2D1, 3C3D1, 3P1D1, 3P2D1, 3P3D1, 3P4D1, 3P5D1, 3P6D1, 3P7D1, 3P8D1, 3P9D1, 3P10D1. |
| | | Wet (March – May 2000) | 3U1W1, 3U2W1, 3U3W1, 3U4W1, 3U5W1, 3U6W1, 3U7W1, 3U8W1, 3C1W1, 3C2W1, 3C3W1, 3P1W1, 3P2W1, 3P3W1, 3P4W1, 3P5W1, 3P6W1, 3P7W1, 3P8W1, 3P9W1, 3P10W1. |
| | | Dry (June – July 2000) | 3U1D2, 3U2D2, 3U3D2, 3U4D2, 3U5D2, 3U6D2, 3U7D2, 3U8D2, 3C1D2, 3C2D2, 3C3D2, 3P1D2, 3P2D2, 3P3D2, 3P4D2, 3P5D2, 3P6D2, 3P7D2, 3P8D2, 3P9D2, 3P10D2. |

## 4.7 Performance of Constructed Wetlands

As this is the preliminary study of the first constructed wetlands in Malaysia, it is important to understand how the constructed wetlands perform and its removal efficiency. However, the results obtained for the performance of constructed wetlands is obtained by concentrating the results of water quality parameters from Upper North wetland cells, which is considered as inflow (In) and Primary Lake as outflow (Out). The water quality data was obtained from October 1999 to July 2000 where wetland plants were planted in the wetland cells. This is the maintenance period of constructed wetlands where the plants has matured, no more construction activities involved and the ecosystem of the wetland systems had started to stabilize and perform.

Overall, the results obtained for the performance of treating pollutants in constructed wetlands are satisfactory. Table 45 and Figures 77 – 83 indicate the means and standard deviations of each of the water quality parameters and the water quality index (WQI) obtained and the percentage of changes in water quality parameters in the inflow and outflow. It was observed that there were changes in mean pH, DO, COD and TSS values in the inflow and outflow. The mean pH values for inflow and outflow ranged from 6.0 ± 0.2 to 6.5 ± 0.3 (Figure 77). The variation for inflow was lower (5.9 to 6.4) compared with outflow (5.9 to 7.2). The mean DO values in inflow was 5.7 ± 0.4 mg $L^{-1}$ with variation between 4.4 to 6.3 mg $L^{-1}$. The mean inflow was higher compared to the mean outflow DO values which was 6.3 ± 0.4 mg $L^{-1}$ which varied between 5.6 to 7.0 mg $L^{-1}$ (Figure 78). Mean COD values in outflow were found to be higher (7.5 mg $L^{-1}$) compared with the inflow (7.1 mg $L^{-1}$). The mean COD values in the inflow and outflow ranged from 1.5 to 10.6 mg $L^{-1}$ and 1.5 to 15.4 mg $L^{-1}$ respectively (Figure 80). The mean inflow TSS values were 21.1 mg $L^{-1}$ with variation between 9.9 to 45.8 mg $L^{-1}$. The mean inflow was higher compared to the mean outflow TSS values, which was 8.2 mg $L^{-1}$ and varied between 4.8 to 12.5 mg $L^{-1}$ (Figure 82). However, as for mean BOD and AN values, there was no changes found in the inflow and outflow.

As for the WQI, the mean WQI for inflow and outflow recorded was 84.3 ± 3.1 to 88.6 ± 2.8. The mean inflow WQI was lower compared to outflow, which ranged between 79.1 to 88.3 and the outflow ranged from 85.2 to 89.9.

**Table 45. Mean Performance Data from for Putrajaya Constructed Wetlands**

| Months | | pH | | DO | | BOD | | COD | | AN | | TSS | | WQI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | In | Out | In | Out | In | Out | In | Out | In | Out | In | Out | In | Out |
| October 1999 | Mean | 6.1 | 6.5 | 6.2 | 6.7 | 2.0 | 2.0 | 9.0 | 1.5 | 0.5 | 0.5 | 17.8 | 7.3 | 84.7 | 89.3 |
| | SD | (0.3) | (0.3) | (0.3) | (0.1) | (0.0) | (0.0) | (8.5) | (1.0) | (0.2) | (0.1) | (7.0) | (0.5) | (3.1) | (1.2) |
| November 1999 | Mean | 6.4 | 7.2 | 6.0 | 5.8 | 3.1 | 1.8 | 9.4 | 7.7 | 0.3 | 0.1 | 45.8 | 12.5 | 83.5 | 89.3 |
| | SD | (0.3) | (0.7) | (0.2) | (0.2) | (0.6) | (0.4) | (2.1) | (3.4) | (0.1) | (0.0) | (25.5) | (3.1) | (1.8) | (1.1) |
| December 1999 | Mean | 6.2 | 6.7 | 6.1 | 6.5 | 2.2 | 2.0 | 6.0 | 5.8 | 0.2 | 0.4 | 9.9 | 5.4 | 88.3 | 89.9 |
| | SD | (0.1) | (0.3) | (0.6) | (0.5) | (0.3) | (0.0) | (6.5) | (6.9) | (0.2) | (0.7) | (7.1) | (2.8) | (2.8) | (4.8) |
| January 2000 | Mean | 6.0 | 7.0 | 4.4 | 5.8 | 2.0 | 2.2 | 9.4 | 15.4 | 0.3 | 0.3 | 19.3 | 10.8 | 79.1 | 85.5 |
| | SD | (0.2) | (0.4) | (0.4) | (0.3) | (0.0) | (0.2) | (6.6) | (5.0) | (0.2) | (0.1) | (19.8) | (13.7) | (3.0) | (2.5) |
| February 2000 | Mean | 5.9 | 6.5 | 5.3 | 5.6 | 2.0 | 2.0 | 10.6 | 15.0 | 0.3 | 0.3 | 17.1 | 9.3 | 82.4 | 85.2 |
| | SD | (0.2) | (0.2) | (0.5) | (0.5) | (0.0) | (0.1) | (5.0) | (8.8) | (0.1) | (0.1) | (9.1) | (2.9) | (4.0) | (2.3) |
| March 2000 | Mean | 6.0 | 6.3 | 6.2 | 6.4 | 2.0 | 2.0 | 1.5 | 6.8 | 0.3 | 0.3 | 19.4 | 7.0 | 87.7 | 89.6 |
| | SD | (0.2) | (0.3) | (0.4) | (0.3) | (0.0) | (0.0) | (1.4) | (5.3) | (0.3) | (0.5) | (5.0) | (5.7) | (2.3) | (2.6) |
| April 2000 | Mean | 6.0 | 6.1 | 5.8 | 7.0 | 2.0 | 3.1 | 4.1 | 7.2 | 0.2 | 0.3 | 15.6 | 5.5 | 87.8 | 89.1 |
| | SD | (0.2) | (0.2) | (0.4) | (0.6) | (0.0) | (2.1) | (3.6) | (5.7) | (0.1) | (0.4) | (9.2) | (2.1) | (2.2) | (4.9) |
| May 2000 | Mean | 6.1 | 6.7 | 5.8 | 6.0 | 2.0 | 2.2 | 5.8 | 6.2 | 0.3 | 0.4 | 23.4 | 4.8 | 85.8 | 89.6 |
| | SD | (0.1) | (0.4) | (0.3) | (0.2) | (0.0) | (0.3) | (5.7) | (6.9) | (0.1) | (0.6) | (6.0) | (1.5) | (1.9) | (4.1) |
| June 2000 | Mean | 5.8 | 6.5 | 4.6 | 6.2 | 2.0 | 2.4 | 6.1 | 8.0 | 0.4 | 0.2 | 16.5 | 8.8 | 80.5 | 88.9 |
| | SD | (0.3) | (0.3) | (0.3) | (0.4) | (0.0) | (0.7) | (4.7) | (8.9) | (0.4) | (0.1) | (12.8) | (3.8) | (3.0) | (3.0) |
| July 2000 | Mean | 5.9 | 5.9 | 6.3 | 6.6 | 2.3 | 2.0 | 8.6 | 1.6 | 0.6 | 0.3 | 25.8 | 10.8 | 83.6 | 89.1 |
| | SD | (0.3) | (0.2) | (0.5) | (0.4) | (0.8) | (0.0) | (6.7) | (1.9) | (0.7) | (0.1) | (14.5) | (3.1) | (6.5) | (1.8) |
| | Mean | 6.0 | 6.5 | 5.7 | 6.3 | 2.2 | 2.2 | 7.1 | 7.5 | 0.3 | 0.3 | 21.1 | 8.2 | 84.3 | 88.6 |
| | SD | (0.2) | (0.3) | (0.4) | (0.4) | (0.2) | (0.4) | (5.1) | (5.4) | (0.2) | (0.3) | (11.6) | (3.9) | (3.1) | (2.8) |
| | % of changes | 8.3 | | 10.5 | | - | | 7 | | - | | **61.1** | | 5.1 | |

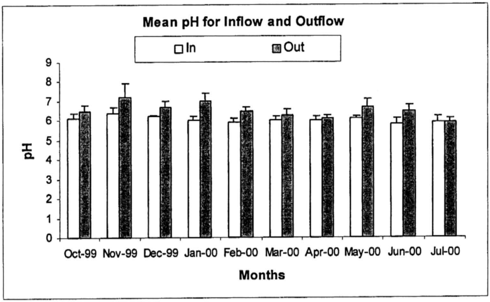


**Figure 77. Mean pH in Inflow (UN) and Outflow (PL)**

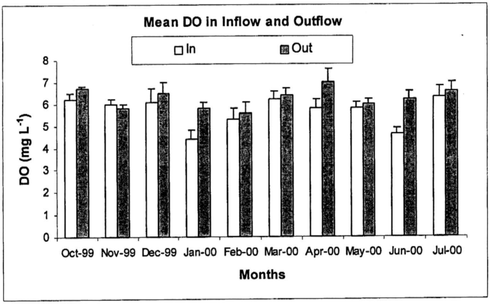


**Figure 78. Mean DO in Inflow (UN) and Outflow (PL)**

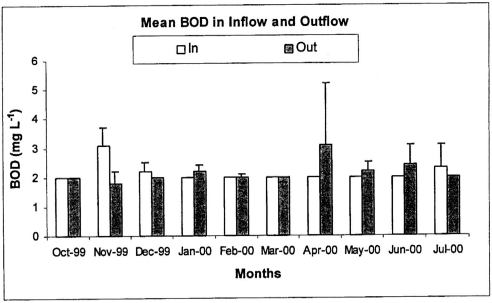


**Figure 79. Mean BOD in Inflow (UN) and Outflow (PL)**

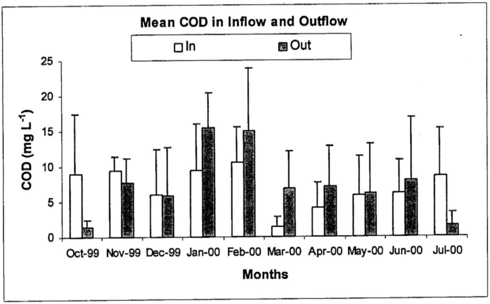


**Figure 80. Mean COD in Inflow (UN) and Outflow (PL)**

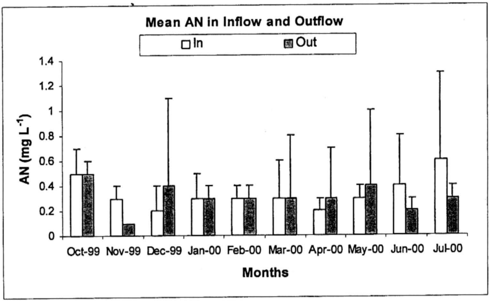


**Figure 81. Mean AN in Inflow (UN) and Outflow (PL)**

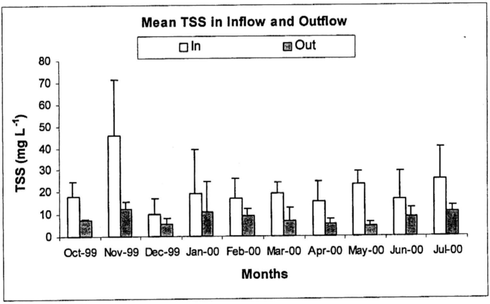


**Figure 82. Mean TSS in Inflow (UN) and Outflow (PL)**

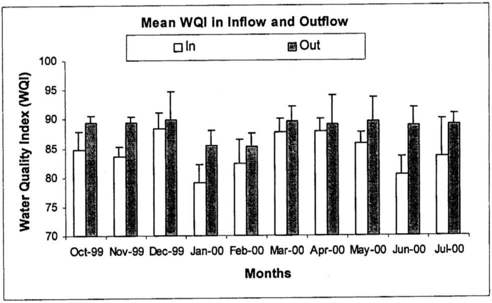


**Figure 83. Mean WQI in Inflow (UN) and Outflow (PL)**