Compilation of Interim Report, Design Guidelines and Observation Report

For the Constructed Wetlands in the City of Elmina

For:

Sime Darby Property

Prepared by:

Wetlands International

Table of Contents

List of figures

Part 01:

Part 02:

Part 03:

List of tables

Part 01:

Part 02:

Part 01: Interim Report for Sime Darby Elmina Development (City of Elmina)

Interim Report for Sime Darby Elmina Development (City of Elmina)

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Introduction

Background

The Sime Darby Properties development of the City of Elmina covers an area of 5,000 acres of land which is proposed to be developed for residential, commercial, industrial, public amenities, infrastructure/utilities, open space and detention pond.

Much of the site consists of the former Sime Darby Plantations agricultural land under oil palm production, and the area is located between the Subang and Sungai Buloh districts in Selangor. The development is accessible via the Guthrie Corridor Expressway (GCE) which runs through the site. The area is also situated adjacent to the Bukit Cherakah Forest Reserve and reservoir catchment forest, one of the few remaining patches of tropical lowland rainforest remaining in the State of Selangor.

The vision of Sime Darby in the development of the City of Elmina has been to “embody wellness and embrace the art of living well”. The development forms an important component of the Selangor Vision City - the township that is the catalyst for growth in the Guthrie Corridor. As such, Sime Darby Properties have incorporated extensive green spaces and public spaces into this development. These include parks and gardens, a wellness hub, and up to 90km of cycling and jogging tracks. As wetlands form an important component within the City of Elmina, Sime Darby Elmina Development Sdn Bhd (SDED) have engaged the services of Wetlands International Malaysia to provide inputs on the design and management of the wetlands on site, and to provide recommendations for the further development of this project.

Goal

To assist SDED in developing healthy wetlands that will serve as a Best Practices model for future housing developments.

Objectives

- To develop guidelines for healthy wetland design, operation and maintenance.
- To produce a checklist for to be used as reference in designing to achieve ‘A’ class standards for wetlands.

Wetlands International’s role

Wetlands International Malaysia are part of an international network of NGOs that focus on wetlands and the biodiversity and people they support. Wetlands International has been established in Malaysia since 1996 and has worked on numerous projects to showcase urban green spaces, and increase the potential to attract desirable wildlife into urban settings.

Our role in this project for the City of Elmina is to develop a set of design, operation and maintenance guidelines for SDED. These guidelines will be used as reference for the design, development, operation and maintenance of current and future wetland ponds within the City of Elmina. Wetlands International will also develop a wetland health assessment checklist which contains indicators that will help SDED in assessing their wetland health.

Current status of ponds for City of Elmina

A total of 27 ponds are planned for the City of Elmina. The ponds are made up of various size and layout and are in different completion stages. The list below indicates the different ponds of CoE and their status.

Table 1: List of ponds at CoE

Category	Denai Alam	Elmina East	Elmina West
Completed	Pond A Pond B Pond C Pond D	Pond 5 Pond 6	Pond 9
On-going		Pond 4	Pond 2 Pond 3 Pond 10
Future		Pond 1 Pond 2 Pond 3 Pond 7	Pond 1 Pond 4 Pond 5 Pond 6 Pond 7 Pond 8 Pond 11 Pond 12 Pond 13 Pond 14 Pond 15 Pond 16

Table 2: List of river at CoE

Category	Denai Alam	Elmina East	Elmina West
On-going		Sungai Subang	Sungai Subang

Methodology

A total of eleven small water bodies (ponds) and parts of the Sungai Damansara were included in the rapid assessment survey at Elmina City. These included four water bodies in Denai Alam; three in Elmina East and four in Elmina West (**Figure** 1) below shows the locations of these waterbodies).

Figure 1: Location of waterbodies surveyed.

Visits were conducted to the Elmina City on 4th and 6th March 2019. Field visits were made to a series of wetlands highlighted and prioritized by the SDED staff. In total, 10 ponds and sections of the adjacent and adjoining Sungai Damansara and other drainage areas, were surveyed. The survey team was led by Ms. Denise Cheah (technical officer for Wetlands International Malaysia, specializing in wetland management and functions) together with Wetlands International associate experts - Mr.

John Howes (consultant ecologist, Luscinia Consulting Sdn. Bhd., specializing in wetlands and birds); and Dr. Choong Chee Yen (professor at UKM, Malaysia, specializing in dragonflies and damselflies, Odonata).

Field surveys were conducted from 9am to 5pm on both days. Each pond (water body) was visited for a minimum of about 1 hour where during that time all species of birds, Odonata and other obvious species were recorded.

Bird observation was conducted with a pair of Swarowski 10x40 binoculars and a Kowa 25-60x field telescope. Photographs of some bird and Odonata species were taken using a Samsung A8+ handphone fitted with a Kowa telescope adapter. Birds were identified to species level using a local field guide (Jeyarajasingam and Pearson, 1999), as well as through identification of calls and song. Odonata were identified using a local pocket guide (Orr, 2005).

***Note:** The term Sungai Subang is used to depict the river that flows eastwards out from Bukit Cherakah Forest Reserve to the west of CoE. Based on map information, the closest river to the development is Sungai Damansara.

The term Bukit Cherakah Forest Reserve is used to depict the forest adjacent to the development in Elmina West. According to the Forestry Department of Peninsular Malaysia, the forest reserve adjacent to the CoE development was made up of a larger forest reserve area known as the Sungai Buloh Forest Reserve (which included the Bukit Cherakah Forest Reserve and former Subang Forest Reserve). In the 1990s, parts of the Sungai Buloh Forest Reserve namely all of Subang Forest Reserve and bits of Bukit Cherakah Forest Reserve were used for development by FELDA though there was no official degazettement of the Forest Reserve.

Results

Wetlands description and analysis

An overview description of each water body is provided below with the assessment of general conditions of the site. The description is divided according to the three sections namely Denai Alam, Elmina East and Elmina West.

Wetlands in Denai Alam

Pond A

Figure 2: Google Earth satellite image (29-4-2017) of Denai Alam Pond A showing extent of maturity of the pond and surrounding environment.

Pond A was not surveyed in detail due to the time of the day where majority of the birds and wildlife are inactive though a quick assessment was carried out at the area. According to bird expert and ecologist, John Howes, it is unlikely that any rare or unusual species will be spotted at the area given the conditions of Pond A - its size (smallest amongst all the ponds) and similarity in terms of conditions to the other established ponds in Denai Alam where biodiversity is generally low. It is concluded that the pond will not show high levels of biodiversity based on observations and comparisons with other pond sites.

Pond B

Figure 3: Google Earth satellite image (6-12-2017) of Denai Alam Pond B showing extent of maturity of the pond, and evidence of its eutrophic status in the South-East section of the pond.

This pond is a fairly mature sediment retention pond within the Denai Alam section of the Elmina City development. The pond is oriented in a North-West to South-East direction and is approximately 250m long and 80m wide. The pond drains into the Sungai Damansara catchment from a sluice gate in its South-East corner, the exit drain feeding eventually into Denai Alam Pond D (see **Figure 3** above).

The pond is surrounded on its North-Eastern, Eastern and South-Eastern edges by mature woodland consisting of mostly *Acacia mangium*, although there are some native *Macaranga* spp. also present. The other sides of the pond consist of open, grass and shrub vegetation. The satellite image shows dense aquatic vegetation around the fringes of the pond. However, a recent visit to the pond shows otherwise. Majority of the vegetation is no longer present, only clumps of wetland plants remain around scattered patches on the east side of the pond (**Figure 4**).

The pond is probably relatively shallow (<2m in depth) due to sedimentation. Visual water quality is generally poor, with a lot of suspended sediments, and extensive, floating algal mats around the exit sluice, leading to a generally eutrophic water body (**Figure 5**).

Figure 4: Current condition of Pond B.

Figure 5: Algae mat in Pond B near culvert.

Pond C

Figure 6: Google Earth satellite image (31-12-2016) of Denai Alam Pond C showing extensive beds of aquatic plants which shows to be lotuses (*Nelumbo nucifera*) from previous ground surveys, and evidence of high volume and high velocity flows into and through the ponds (depicted by areas of brown-coloured open water in the image).

Google Earth satellite images from late 2016 indicate that Pond C in Denai Alam was at one time a well vegetated water retention pond. The "pond" actually consists of two separate ponds, connected by a sluice gate in the middle. The larger North-South oriented path is approximately 230m in length and 100m at its widest point. The smaller "feeder" pond in the East is a circular pond of between 50 and 60m in diameter (**Figure 6**).

In March 2019 the entire pond was under-going a dredging operation to remove accumulated sediments, and was largely denuded of any aquatic vegetation which is a shame as the area to the east of the pond had been landscaped into a recreational park with visitor infrastructure consisting of small shelters and viewing platforms around the pond. Dredged sediments had been piled up at the Southern end of the pond (presumably to be removed to another site eventually). Small patches of Sacred Lotus (*Nelumbo nucifera*) remained indicating that in late 2016, it was the dominant vegetation shown on the satellite image. The wetland plant *Limnocharis flava* was also spotted in small, isolated patches around the pond.

Figure 7: Current condition of Pond C.

Figure 8: *Limnocharis flava* with lotus leaves visible in the background.

Pond D

Figure 9: Google Earth satellite image (12-06-2017) of Denai Alam Pond D showing extensive beds of aquatic plants throughout pond.

This pond is a large retention pond adjacent to the Guthrie Corridor Expressway, orientation is North-West to South-east the pond is approximately 275m in length and with an average width of around 60m. The pond was historically almost completely covered with aquatic floating plants (species undetermined, as per the Google earth satellite image of 12th June 2017) **(Figure 9**). In March 2019 the pond was largely clear of any aquatic plants (possibly indicating a recent dredging to remove sediments).

Visible water quality was good, with visibility to at least 1m in depth and evidence of a low eutrophic status with few algae or green colouration of the water (**Figure 10**).

Much of the pond is surrounded by short grassland, which is possibly grazed by cows. To the North-West of the pond a series of shallow wet depressions indicates the historical route of the river and its connectivity between Ponds B and D in Denai Alam.

The pond is fed largely from run-off and drainage from the Denai Alam development to the North-West and exits into the Sungai Damansara catchment to the South.

Figure 10: Current condition of Pond D, Denai Alam.

Wetlands in Elmina East

Pond 4

Figure 11: Google Earth satellite image (29-4-2017) of Elmina East Pond 4, showing proximity to Sg. Subang and woodland perimeter.

The pond is rather sinuous in nature, about 550m in length and between 15 and 60m wide, orientated in a S-N direction along the floodplain of the Sungai Subang about 60m to the west (as measured using Google Earth) (**Figure 11**). This pond was relatively undisturbed, as access to it (at this point in time) was only via foot. The area surrounding the pond was also in a fairly "natural" state (**Figure 12**), with a fringe of woodland, consisting of large trees around most of the periphery. In addition, there is a more or less contiguous, but thin littoral fringe of aquatic plants around the pond shoreline. Visually, the water quality appeared to be good, with clear water and little sediment. Along the eastern shore, the sandy bottom sediments could be easily seen, to a depth of about 3m.

Whilst Pond 4 appears to be in quite a "natural" state, it is in fact a highly modified water body. The original floodplain functioning of the pond (absorbing and storing flood water from the adjacent Sungai Subang during period of high water, and slow release of those waters back into the river during drier periods), had been significantly compromised. There was no evidence of an in-flow or out-flow sluice gate or drain connecting the Sungai Subang with the pond. In addition, a track along the top of a raised bund had been constructed between the river and the western edge of the pond, cutting off any natural flows of flood waters into the pond and also any seepage and outflow. The clarity of the pond water, its' clean sandy sediments, the lack of suspended sediment and mud, support the theory that Pond 4 has in fact been isolated from the Sungai Subang for some time.

There is also anecdotal evidence to indicate that the pond ecosystem is probably quite unproductive. No shoals of small fish were recorded in the shallows, no amphibian life (frogs and toads) and little aquatic insect life, other than adult flying Odonata, were observed.

In addition, more or less 100% of the fringing woodland consisted of two species of alien, exotic trees from Australia – *Acacia mangium* (Big-leaved Acacia) and *Acacia auriculiformis* (Yellow Acacia). These species are typical pioneer communities of cleared land in Malaysia, and out-compete local pioneer tree species in situations where the soil conditions, exposure and temperatures are high (such as are typically found on land immediately after it is cleared for development). These types of "mono-culture woodlands", consisting of alien species are unlikely to support significant populations of insect and bird life.

The littoral fringes of the pond have been recently colonized by pioneer aquatic plant communities, and a narrow fringe has developed. The plants mostly consist of *Carex* spp. (sedges) with small patched of *Sagittaria* sp. (arrowheads) – these are both typical pioneer groups that are likely to have developed from seeds in the "seed bank" of the pond. With no, or limited connectivity, to the Sungai Subang, it is unlikely that these fringing vegetation communities will develop to a climax vegetation.

Land clearance for development of the area immediately adjacent to the pond to the east has led to soil erosion along the slopes and deposition into the pond, especially in areas where no surrounding tree cover is found. In addition, it was observed that rock filled "gabions" had been placed along the eastern edge of the pond, below current water levels, probably as a protective measure to prevent slippage of banks and erosion of the pond edges.

Figure 12: Pond 4 Elmina East (Photos by John Howes ©Wetlands International Malaysia).

Pond 5

Pond 5 consists of a rather sterile, typical sediment retention pond wetland. The pond edges are steep (and in places artificially reinforced), resulting in no development of littoral fringing vegetation communities, and the pond basin is surrounded by more or less manicured grass with the occasional planted tree – creating an artificial "park-scape". The site has been developed as a community park with cycling and running tracks and several small shelters for visitors. There were few birds or other biodiversity recorded at Pond 5 in March 2019, quite typical of such newly created and planted systems. In some areas, small patches of *Melaleuca* sp. (tea-tree sp.) trees have been planted, this species is ecologically suitable for the flood zone and can be attractive to birds and insects too.

Pond 5 is fairly small (maximum length only 250m; and a maximum width of 150m, although most of it is less than 50m in width). The pond is oriented in SW-NE direction and is located about 50m north-west of the Sungai Subang. The pond is about 340m downstream of Pond 4 (see above), and historically would have been hydrologically connected via the Sungai Subang. The north-east perimeter of the pond consists of a high retention wall, created during the construction of the major road bisecting this pond from Pond 6 (**Figure 13**).

Historically the pond would have been directly connected to the Sungai Subang, but the construction of a high retaining bank to the east now cuts off any natural hydrology and water exchange. The out-flow sluice to the Sungai Subang is located in the eastern corner of the pond (and this may act as an in-flow sluice during times of flood). However, the pond probably gets most of its inflow from surface run-off from surrounding land, drains and roads. Water quality was generally poor visibly, with evidence of fine suspended sediments and algal blooms observed in March 2019.

Figure 13: Pond 5 Elmina East (Photos by John Howes ©WI Malaysia).

Pond 6

This pond is immediately to the north-east of Pond 5, on the other side of a major road embankment (**Figure 14**). Prior to development, it would have been a part of the same floodplain wetland as Pond 5, with a direct connection to the Sungai Subang. The pond is rather small, in a more or less triangular configuration, with maximum length and width of 140m x 180m.

Figure 14: Google Earth satellite image (29-4-2017) of Elmina East Ponds 5 and 6, showing proximity to Sg. Subang and intersection of main roads.

There is an out-flow sluice to the Sungai Subang located in the south-eastern part of the pond (and this may act as an in-flow sluice during times of flood). However, the pond probably gets most of its in-flow from surface run-off from surrounding land, drains and roads. Water quality was generally poor visibly, with evidence of fine suspended sediments, algal blooms and plastic and polystyrene litter observed in March 2019. Levels of sedimentation into Pond 6 are probably quite high, as a wide shallow fore bay of deposited sediments was forming along the eastern edge of the pond. This area has been colonized by aquatic plants (*Carex* spp. and other grasses) and created quite good habitats for wildlife.

An interesting aspect of this area is the adjacent Sungai Subang floodplain channel of around 50 to 60m width that has been maintained by the developer (to alleviate flooding of the housing development during periods of high flow). In places this channel is interesting for biodiversity. The un-developed grassland along the floodplain channel has been planted with groups of trees, and in places these are now forming quite dense stands of trees. These areas should be left as natural as possible to allow natural regeneration of floodplain vegetation communities, with supplementary planting of suitable tree and other species that can withstand the water flow velocities during flood events.

An observation noted at both Pond 5 and Pond 6 was the unusual planting of what seems to be *Typha sp*. A row of *Typha* has been planted along the banks of the pond to form presumably a barrier of sorts (**Figure 15**) though It is uncertain the purpose of the abnormal planting method.

Figure 15: *Typha* strands planted in the ground.

Wetlands in Elmina West

Pond 2

Figure 16: Google Earth satellite image (6-12-2017) of Elmina West Pond 2 under construction.

Unlike the modified floodplain ponds and retention basins described in Elmina East above, Pond 2 in Elmina West is completely artificial. Prior to development there was no pond or wetland basin in this area, although Google Earth images from 17-7-2016 indicate that a small river flowed through this area when under oil palm. The image indicated is an old image from 2017 as 2018 images showed cloud cover hence it could not be applied.

The contractors have sculptured a kidney-shaped basin, with estimated maximum dimensions of 500m length x 200m width, orientated in an East-West direction (**Figure 16**). The aim of the development is to develop a park-scape and wetland feature for local residents to enjoy. The design includes a "lotus pond" – which will also act as a filter system for drainage in-flows from the housing development. There will also be a feature bridge across the lotus pond and a tree-lined avenue along the perimeter of the pond, leading to a viewing area on the eastern side.

Gross litter traps have been constructed on in-flow and out-flow gates. The main in-flows will of wastewater and run-off from the housing area to the south. The exit sluice will empty into a small channel in the south-east corner of the pond, flowing southwards towards Elmina West Pond 3 (**Figure 17**).

During March 2019, the pond was still under construction, disturbance levels were high and few species of bird were observed at this stage.

Figure 17: Pond 2 still under construction.

Pond 3

Figure 18: Pond 3 of Elmina West.

This pond is within a small natural depression about 600m south of Pond 2 (**Figure 18**). It is unclear if the two sites are hydrologically connected, but there appears to be a small water course on Google earth images from 2017. In March 2019 Pond 3 was no existent. The entire site was being re-sculptured and modified. Images from 6th December 2017 indicate that the site is a run-off basin with high levels of sedimentation and excessive vegetation, leading to the conclusion that the pond was eutrophic at this time.

Pond 9

Pond 9 in Elmina West is the main feature lake of the Community Park development. The site is a landscaped park-scape including two lakes, manicured lawns and scattered trees, with visitor infrastructure including shelters, viewing platforms, picnic areas and running and cycling tracks. Many of the planted trees are mature or semi-mature specimens of native, tropical forest trees. The trans-planted trees are on the whole growing well.

The pond is fed by surface run-offs and exits into the Sungai Subang which discharges under the main Guthrie Corridor Expressway and continues through Elmina East (adjacent to Elmina East Pond 4). The pond is sinuous in form, more or less following the floodplain valley of the river, and is approximately 1300m long and up to 50m wide. The system is orientated within an East-West direction at the centre of the Elmina City development (**Figure 19**).

The central pond is steep-sided with artificial edging around most of its' perimeter (**Figure 21** and **Figure 22**). Despite this, there is some development of a littoral fringe of aquatic vegetation, especially where the central cement walkway crosses the lake and creates a barrier to waterflow. Some *Cabomba* sp. was also sighted along the central cement walkway but a more detailed inspection is required to confirm this.

Visible water quality is fairly poor, with evidence of algal accumulation leading to slight eutrophic water conditions. Despite this, aquatic insect life was diverse, especially amongst the Odonata, indicating that the water body is probably quite productive.

Figure 19: Google Earth satellite image (6-12-2017) of Elmina West Pond 9 (eastern section only) during construction of Elmina City Central Park in late 2017.

Figure 20: Elmina West Pond 9 with some wetland plants growing along the banks.

Figure 21: Sungai Subang running through Elmina West – Elmina City Central Park, showing raised walkway across lake and turbid water quality (Photo by John Howes ©WI Malaysia).

Figure 22: Steep slopes of river edge with little or no wetland vegetation at Sungai Subang.

Pond 10

Despite the small size, Elmina West Pond 10 is one of the most interesting within the Elmina City development. The "pond" actually consists of two small flood retention ponds adjacent to (south-east of) the Sungai Subang where it discharges from the Bukit Cherakah Forest Reserve. Due to its' location at the edge of the forest the site has potential to attract different biodiversity to the other ponds, as species of birds in particular using the forest edge may move into this area once the development matures (**Figure 23**).

The ponds were probably historically connected to the Sungai Subang as part of its floodplain wetlands. However, they are now separated by a high retention bank and linked through sluice gates and function as run-off and drainage collection ponds. The two ponds are at differing heights which creates a cascading flow, with terraces between the ponds to aerate the run-off water before it exits into the Sungai Subang.

Both ponds are shallow (probably less than 2m in depth) due to sedimentation over the years, and both have developed an interesting fringe of littoral aquatic vegetation, consisting mnostly of sedges (*Carex* spp.) and arrowheads (*Sagittaria* spp.). The upper (westernmost) pond has a small island developing at its western end, and this is being developed into a larger island in the hope of attracting birds.

Figure 23: Google Earth satellite image (6-12-2017) of Elmina West Pond 10 showing proximity to edge of Bukit Cherakah Forest Reserve (on the left), terracing of upper pond and in-flow sluices to the Sungai Subang to the north-east.

Figure 24: Elmina West Pond 10 – Lower Pond, showing littoral aquatic vegetation (Photo by John Howes ©WI Malaysia).

Figure 25: Elmina West Pond 10 – Upper Pond, showing terraced cascade.

Sungai Subang

Multiple observations were carried out along selected stretches of Sungai Subang – namely Elmina West (pond 9 & 10), Elmina East (pond 6, **Figure 27**). The Sungai Subang flows from Bukit Cherakah Forest Reserve and cuts through Elmina West heading towards Elmina East.

Close to the edge of the forest reserve, the water flowing out from the forest reserve is generally clear though there were parts of it where the water was muddy. It is most likely due to erosion of exposed soil from the surrounding oil palm plantation and construction activities. Cows have been seen grazing along the river which causes minor desertification through grazing activities and further contributes to sediment run-offs.

Travelling further down, the discolouration of Sungai Subang is especially apparent in the Elmina Central Park area. This is no doubt due to sediment run-off from construction activities in the surroundings. Throughout the area, there were no visible silt traps noticed nor were there any form of protective barrier which would reduce sediment run-off from the construction site to the river. Steep slopes and the lack of fringing vegetation to slow water flow and trap sediments also contributes to the cause for the milky brown colour of the river especially during heavy rainfall.

Moving away from Elmina West to Elmina East where development and construction activities are completed, it can be seen that the river has changed from a milky brown to greenish water. This indicates the presence of algae in the water due to high nutrients levels.

Sungai Subang receives water from the surrounding ponds and surface run-offs of varying sources which includes but not limited to oil, grease, fertilisers and nutrient run-offs. Without proper treatment or the presence of wetland vegetation to absorb the excess nutrients in the water, it will eventually cause eutrophication – a state where excessive nutrient content in the water body induces the growth of algae. This may result in oxygen depletion of the water body which is detrimental to the aquatic ecosystem further downstream.

Figure 26: Sungai Subang flowing from the Forest Reserve.

Figure 27: Sungai Subang flowing behind Elmina East Pond 6.

Biological diversity assessment

Avifauna

A total of 48 species of birds were recorded at the ten survey sites within Elmina City during early March 2019 (**Table 3** provides a breakdown of species and sites). This amounts to only about 7% of all bird species recorded in Peninsula Malaysia. "Sites" were not restricted to the water bodies / ponds alone, but also included surrounding habitats such as woodlands and in most cases the nearby river channels.

This is likely to be an under-recorded total, because a) surveys took place only over two days; b) peak migration season has not yet started; and, c) no nocturnal (night-time) surveys were not undertaken. It is estimated that perhaps up to 100 species may be found at Elmina City once the area is fully developed.

The most commonly recorded species were Javan Myna (Acridotheres javanicus), House Crow (*Corvus splendens*) and Swiftlet spp. (*Aerodramus* spp.). These are all typical, common urban species, and the first two are in fact alien species introduced to Malaysia. The Javan Myna is an Indonesian species that was imported as a popular cage bird into Malaysia and Singapore during the 1970s, from wher it has accidently escaped and is npow one of the most dominant elements of the urban bird fauna. The House Crow was introduced into Malaya during the late 1800s from Sri Lanka, in an attempt to control insect pests in rubber estates. However, with the growth or urban settlements and the lack of waste disposal this species quickly became the urban crow of Malaysia.

Most of the bird species recorded at Elmina City (43 species or 90%) are resident species – that means that they are resident all year in Malaysia and breed in Malaysia. Migrant species, those that breed elsewhere but fly to Malaysia during other parts of their life cycle, only accounted for 10% of all species recorded. This may be due to the fact that the surveys took place in early March, prior to the peak Spring migration period between late March and early May. If surveys can be repeated in April 2019, perhaps more species can be recorded.

Migrant species recorded at Elmina City included several "waterbirds", these are species that are dependent on wetlands to some extent, including Common Sandpiper (*Actitis hypoleucos*) which breeding in northern China and Mongolia and winters in SE Asia; Pintail Snipe (), which breeds in the taiga forests of Russia and NE Asia and winters in SE Asia; and, Little Egret (*Egretta garzetta*), breeding in southern China and wintering in the Asian tropics.

Other migrants recorded included species such as Asian Koel (*Eudynamys scolopacea*), Blue-tailed Bee-eater (*Merops philippinus*), and Barn Swallow (*Hirundo rustica*).

Currently, the most diverse site for birds within Elmina City is Pond 4 in Elmina East. This site is largely undisturbed, retains some mature woodland habitats and its wetlands are developing. The least diverse site for birds in Elmina City was Pond 3 Elmina West – this is unsurprising as the site was still under construction, with high levels of disturbance and little or no water resources.

Records of note and interest, include probable breeding records of Red-wattled Lapwing (*Vanellus indicus*); several sightings of Purple Heron (*Ardea purpurea*); a single Lesser Treeduck (*Dendrocygnus javanica*); and a small breeding colony of Baya Weaver (*Ploceus philippinus*).

Surprisingly absent from the wetlands in Elmina City was the common urban wetland species White-breasted Waterhen (*Amaurornis phoenicurus*) – perhaps due to hunting pressure by migrant workers. As wetland habitats develop further, species such as Painted Stork (*Mycteria leucocephala*) may be expected to colonize if the correct ecological conditions can be created.

Figure 28: Top row (left to right): Red-wattled Lapwing (Vanellus indicus); Blue-tailed Bee-eater (Merops philippinus); House Crow (Corvus splendens). Bottom row (left to right): Little Heron *Butoroides striata*) (top right); and, Spotted Dove (*Streptophelia chinensis*) (bottom left) (All photos by John Howes ©WI Malaysia).

Table 3: Checklist of birds recorded at ten sites within Elmina City between 3rd and 5th March 2019

No.	Bird Species		Elmina East			Elmina West				Denai Alam		
			Pond 4	Pond 5	Pond 6	Pond 2	Pond 3	Pond 9	Pond 10	Pond B	Pond C	Pond D
1	Purple Heron	*Ardea purpurea*	x			x						
2	Little Egret	*Egretta garzetta*			x			x	xx		x	
3	Little Heron	*Butorides striatus*		x				x	x		x	x
4	Yellow Bittern	*Ixobrychus sinensis*			x							
5	Lesser Treeduck	*Dendrocygnus javanica*	x									
6	Black-shouldered Kite	*Elanus caerulus*	x									
7	Brahminy Kite	*Haliastur indus*			x				x			
8	Crested Serpent Eagle	*Spilornis cheela*	x									x
9	Changeable Hawk-eagle	*Spizaetus cirrhatus*							x			
10	Red Junglefowl	*Gallus gallus*	x									
11	Red-wattled Lapwing	*Vanellus indicus*	xx				xx					xx
12	Common Sandpiper	*Actitis hypoleucos*	x		x				x			
13	Pintail Snipe	*Gallinago stenura*	xx									
14	Pink-necked Pigeon	*Treron vernans*	xx	x	x				x			x
15	Spotted Dove	*Streptopelia chinensis*	x	x	x				x	x		x
16	Peaceful Dove	*Geopelia striata*	xx	x	x	x	x	x	xx	x	x	x
17	Common Koel	*Eudynamys scolopacea*	x	x	x				x			
18	Little Bronze Cuckoo	*Chrysococcyx minutillus*	x						x			
19	Greater Coucal	*Centropus sinensis*	x									
20	Large-tailed Nightjar	*Caprimulgus macrurus*	xx									
21	Swiflet sp.	*Aerodramus sp.*	xxx	xx	xx	x	x	x	xx	xxx	xx	xx
22	White-throated Kingfisher	*Halcyon smyrnensis*	x	x	x			x	x		x	x
23	Blue-tailed Bee-eater	*Merops philippinus*	xx		x	x			x			x
24	Dollarbird	*Eurystomus orientalis*							x			
25	Coppersmith Barbet	*Megalaima haemacephala*	x						x			
26	Common Goldenback	*Dinopium javanense*	x						x			
27	Barn Swallow	*Hirundo rustica*	x		x	xx	x		xx	x		
28	Pacific Swallow	*Hirundo tahitica*	x	x	x		x			x	x	x
29	Common Iora	*Aegithina tiphia*	xx	x	x				x	x	x	x
30	Yellow-vented Bulbul	*Pycnonotus goaivier*	xx	xx	x				xx	x	x	x
31	Black-naped Oriole	*Oriolus chinesis*	xx	x	x				x	x		x
32	House Crow	*Corvus splendens*	x	xx	xx	x		x	xxx	xx	xx	xx
33	Oriental Magpie Robin	*Copsychus saularis*							x			
34	Flyeater	*Gerygone sulphurea*	x	x					x			x
35	Common Tailerbird	*Orthotomus sutorius*	x	x	x				x			
36	Ashy Tailorbird	*Orthotomus sepium*	x									
37	Yellow-bellied Prinia	*Prinia flaviventris*	xx		x							
38	Paddyfield Pipit	*Anthus rufulus*	x	x	x	x		xx	xx		x	x

39	Brown Shrike	*Lanius cristatus*	x						xx			x
40	Asian Glossy Starling	*Aplonis panayensis*	xx	x	x					x	x	x
41	Common Myna	*Acridotheres tristis*			x				x			
42	Javan Myna	*Acridotheres javanicus*	x	x	x	x		x	xxx	x	xx	xx
43	Great Myna	*Acridotheres grandis*							xx			
44	Brown-throated Sunbird	*Anthreptes malaccensis*	x	x								
45	Olive-backed Sunbird	*Nectarinia jugularis*							x			
46	Scaly-breasted Munia	*Lonchura punctulata*	xxx	x	x				x			xx
47	Eurasian Tree-Sparrow	*Passer montanus*	x		x	xx			x	x	x	x
48	Baya Weaver	*Ploceus philippinus*	x									
	Total No. of Species / site		**38**	**19**	**25**	**9**	**5**	**8**	**32**	**12**	**13**	**21**

Notes: x = only a single bird recorded / site; xx = two to five birds recorded / site; xxx = more than five birds recorded / site.

Reptilia

Three species of reptile were recorded in March 2019, a single Changeable Lizard (*Calotes versicolor*) at Pond 4 Elmina East; a single Many-lined Sun Skink (*Mabuya multifasciata*) at Denai Alam Pond B; and, a single Water Monitor (*Varanus salvator*) along the Sungai Subang at Elmina West Pond 10.

Odonata

A field survey was conducted on 6th March 2019 at the ponds of City of Elmina. The day started out cloudy but eventually got hotter as the day progresses, which is a good opportunity to survey Odonata as they prefer sunny weather.

The ponds surveyed were Pond 4 in Elmina East, Pond 9 and Pond 10 in Elmina West (**Figure 30**). From the survey conducted, a total of 20 species were recorded consisting of 15 dragonfly and 5 damselfly species (**Table 4** provides a full list of species and sites observed). Overall, the sites were good for Odonata though the number of species recorded was moderate. Most of the species recorded were common pond species. Three uncommon species (*Diplacodes nebulosa*, *Neurothemis tullia* and *Trithemis pallidinervis*) were recorded. Neurothemis tullia is a spectacular dragonfly species with black and white patches on wings, and only a few individuals were spotted at marshes around pond 4. *Ischnura sengalensis* and *Brachythemis contaminata* were found abundantly at pond 10. *Ischnura sengalensis* was frequently spotted at pond 9. On the other hand, *Diplacodes nebulosa* and *Neurothemis fluctuans* were present in high number at pond 4.

All the Odonata species recorded at the City of Elmina are native to Malaysia and are residens of CoE and the surrounding areas, particularly the adjacent forest reserve. Some species might also use the forest reserve as their refuge. Seasonality of Odonata in tropical regions is not obvious unlike those found in temperate regions with clear summer and winter where most Odonata disappear during winter time. In fact, not much research has been done on the seasonality of Odonata in tropical regions hence it is safe to say that the Odonata species (most of them) spotted at the City of Elmina should be seen throughout the year.

Figure 29: Left to right: *Neurothemis tullia* (male), *Neurothemis tullia* (female), and (below) *Trithemis pallidinervis* (female).

Figure 30: Ponds at City of Elmina for odonata survey. Top: Pond 10 Elmina West, middle: Sg. Subang Elmina West, and bottom: Pond 4 Elmina East.

Table 4: Checklist of odonata recorded at three sites within Elmina City on 4th March 2019

	ZYGOPTERA (Damselflies)	Pond A	Pond B	Pond C
	Family Coenagrionidae			
1	Agriocnemis femina (Brauer, 1868)		/	
2	Ceriagrion cerinorubellum (Brauer, 1865)			/
3	Ischnura senegalensis (Rambur, 1842)	/	/	
4	Pseudagrion microcephalum (Rambur, 1942)	/	/	/
	Family Lestidae			
5	Lestes praemorsus decipiens (Kirby, 1893)			/
	ANISOPTERA (Dragonflies)			
	Family Libellulidae			
6	Acisoma panorpoides (Rambur, 1842)	/	/	
7	Brachydiplax chalybea (Brauer, 1868)			/
8	Brachythemis contaminata (Fabricius, 1793)	/	/	/
9	Diplacodes nebulosa (Fabricius, 1793)		/	/
10	Diplacodes trivialis (Rambur, 1842)		/	
11	Crocothemis servilia (Drury, 1770)	/	/	/
12	Neurothemis fluctuans (Fabricius, 1793)		/	/
13	Neurothemis tullia (Drury, 1773)			/
14	Orthetrum sabina (Drury, 1770)	/	/	/
15	*Pantala flavescens* (Fabricius, 1798)			/
16	Potamarcha congener (Rambur, 1842)	/		
17	Rhodothemis rufa (Rambur, 1842)			/
18	Rhyothemis phyllis (Sulzer, 1776)			/
19	*Tholymis tillarga* (Fabricius, 1798)	/		
20	Trithemis pallidinervis (Kirby, 1889)	/	/	/
	Total number of species	9	11	14

Wetland plants

During the field surveys, we also took the opportunity to survey the wetland vegetation in the surrounding area. Due to the fact that vast majority of the ponds in the project area were constructed or have undergone some form of modification, the wetland vegetation surrounding the pond is not highly diverse.

The ponds at both Elmina East and Elmina West are considered to be relatively young as the vegetation emerging around the fringes of the waterbodies were mostly pioneer sedge and grass species. The only exception is Pond 4 at Elmina East where a strip of *Typha sp.* was observed growing along the western banks. Similar to Elmina East and West, the ponds at Denai Alam had almost zero aquatic vegetation except Pond C with what was formerly known as a lotus bed. Unfortunately, the on-going desilting process has now cleared the lotus bed save for a few scattered patches.

Perhaps the most interesting pond in terms of natural vegetation was found to be at pond 10 of Elmina West where small pockets of littoral vegetation have established along the cascading wetland cells of the area (**Figure 31**). Besides that, colonies of *Scirpus mucronatus* and *Sagittoria latifolia* have established dense strands to form a microhabitat in the lower ridges of the pond. A list of wetland plant species observed at the survey sites are listed in **Table 5**.

Figure 31: Natural establishment of pioneer wetland species.

Figure 32: Broadleaf arrowhead (*Sagittaria latifolia*) and Right: Bulrush (*Scirpus mucronatus*).

Table 5: Checklist of wetland plants recorded within the City of Elmina from 3 – 5 March 2019

No.	**Vegetation**	**Elmina East**			**Elmina West**				**Denai Alam**		
		Pond 4	Pond 5	Pond 6	Pond 2	Pond 3	Pond 9	Pond 10	Pond B	Pond C	Pond D
1	*Eleocharis variegata*						x	x			
2	*Fimbristylis globulosa*							x			
3	*Rhynchospora corymbosa*							x			
4	*Scirpus mucronatus*							x			
5	*Alocasia macrorrhiza*	x									
6	*Sagittaria latifolia*							x			
7	*Typha latifolia*	x	x	x							
8	*Limnocharis flava*						x	x		x	
9	*Nelumbo nucifera*									x	
10	*Nymphaea nouchali*									x	
11	*Carex sp.*	x		x				x	x		

Hydrology

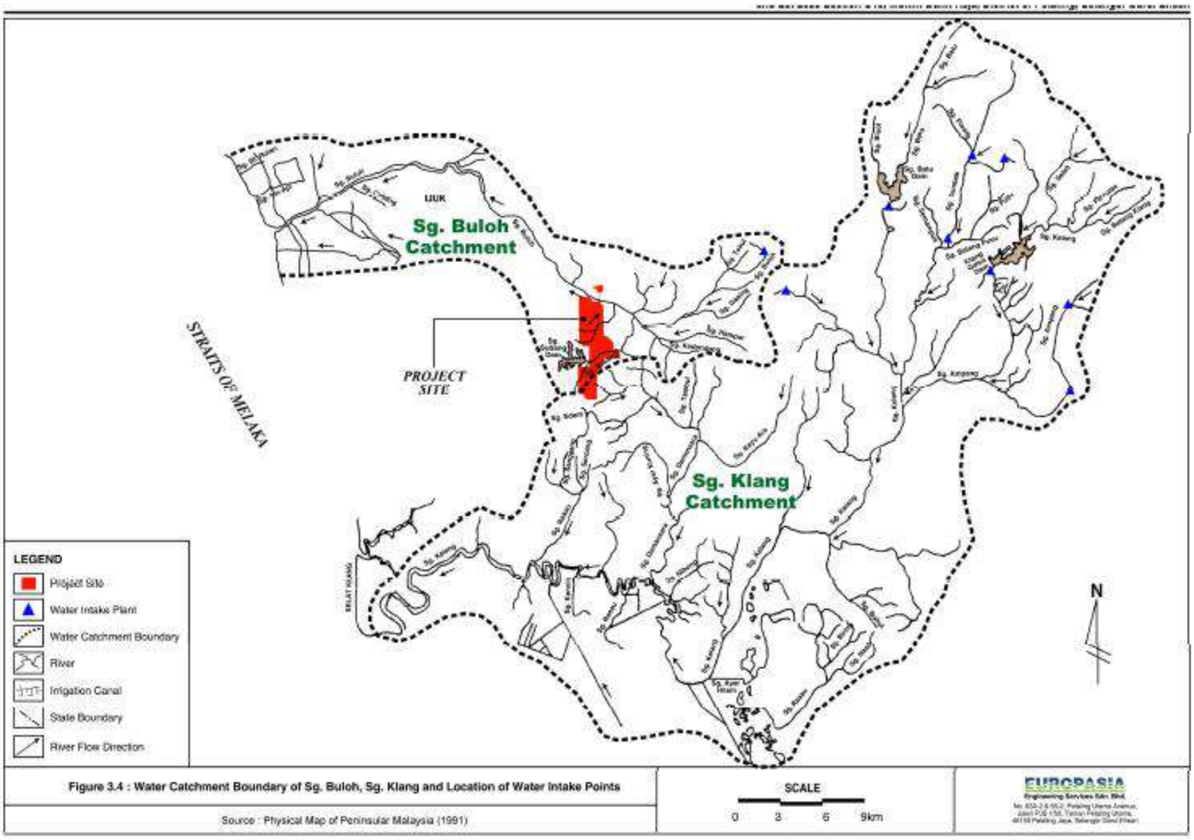

Figure 33: Water catchment boundary of Sg. Buloh, Sg. Klang and Local of Water Intake Points (Source: Europasia).

For wetlands in an urban setting, the most important variable to consider is hydrology. Small changes in a wetland's hydrology can significantly affect the chemical and physical properties of a wetland. These include nutrient availability, substrate anoxia, soil salinity, sediment properties and pH. Similarly, when hydrologic conditions change, plants and animals will respond with shift in species composition and richness. These changes could either enhance or decline productivity.

The Elmina City development straddles two important river basins in Selangor State (**Figure 33**). To the north is the Sungai Buloh basin that flows into the Malacca Straits just north of Jeram and south of Kuala Selangor on the West coast. In the south is the Sungai Damansara basin, which links to the Sungai Klang in the south and flows westwards into the Malacca Straits at Port Klang.

The Sungai Damansara flows in a west to east direction through much of Elmina West and Elmina East, and is the hydrological artery that connects (at least historically) the various ponds along the route. The Sungai Subang flows north easterly and eventually into the Sungai Buloh.

The Sungai Damansara is the main drainage of the southern part of Elmina City, and the Denai Alam section. The Sungai Damansara flows east and south eventually joining the Sungai Klang a Taman Sri Muda near Subang Jaya.

Findings and Identified Potential Issues

Algae issues

Based on observations from the site visits, algae may be a potential issue within the waterbodies of CoE. Algae is found to be present in most of the ponds we have visited and if steps are not taken to address this issue or if the ponds are left unmanaged, it could bloom into something more serious (see **Figure 31**).

Majority of the ponds receive their water from surface run-offs from the surroundings. These nutrient-rich waters are carried directly into the ponds by gravity or during rainfall events. Wetland plants play an important role in nutrient absorption and water purification processes. Without the presence of aquatic plants, the excess nutrients in the water together with ample sunlight will feed the algae colony, causing it to spread faster.

Figure 34: Algae growth noted along the stepping stones in Elmina Central Park.

Siltation and sedimentation

It was observed that despite having crop cover along the slops of the ponds, siltation and sedimentation still occurs within the waterbodies. Due to this, desilting activities will need to be carried out at the ponds. The desilting activities carried out at the ponds were very destructive as we witnessed at Pond C. It is recommended that desilting processes be carried out in stages so to reduce the impact on wetland vegetation. By desilting in stages, it will allow for regeneration by maintaining the seed bank but also to maintain wetland vegetation which serves as a habitat for many of the fauna species. The complete removal of wetland vegetation will drive fauna away, not to mention the loss of vegetation cover will lead to more sedimentation.

Inlet positioning

Observations made at Pond 2 of Elmina West suggest that there may be issues in the future related to desilting maintenance and also hydraulic short-circuiting.

Maintenance access for desilting activities is located away from the inlet zone. The lack of coordination between these two structures would mean that more effort would be required for desilting processes as the machinery will have to cross from one end of the pond to the other. It is assumed that the same practice of complete removal of aquatic vegetation during desiltation activities is going to be applied in all the ponds of CoE.

The position of inlet and outlet structures may potentially cause short-circuiting at Pond 2. Short-circuiting occurs when inflow to the pond flows directly to the outlet with little or no dispersion and results in the direct transport of upstream pollutant loads to the downstream receiving water body.

Recommendations

Potential for increasing habitat structure and biological diversity

Wetlands provide a unique habitat for many species of biodiversity; and, incorporating wetlands into urban development schemes provides opportunities to encourage and attract wildlife to colonize these sites.

In general, the more habitat types and the more habitat structure created will lead to increased biodiversity, and it is therefore essential that habitat diversity and habitat structure are considered when creating and managing wetland features within an urban scape. This may include (but not be excluded to) sensitive planting of fruit-bearing, seeding and nectar-producing tree and shrub species; variable depth wetland zones with differing vegetation types; variable water flows and water quality; suitable nesting and breeding habitats; and, reduced levels of disturbance / increased levels of protection.

The wetlands at Elmina City provide a unique opportunity to attract additional biodiversity due to their proximity to the Bukit Cherakah Forest Reserve and due to their position along the wetland "corridors" that comprise the Subang and Damansara river floodplains. Both of these natural features will act as "reservoirs" or "refugia" and dispersal corridors for the colonization of new species into the area.

Improve hydrology and water flows

Excessive flooding or drought conditions will lead to either the stimulation or the deterioration of a wetland in an urban setting. Accounting for the appropriate frequency of wet/dry cycling is important for maintaining a wetland's productivity.

Most of the existing ponds in the Sungai Subang and Sungai Damansara basins within Elmina City have their origins as floodplain wetland lakes functioning as floodwater retention areas during periods of high water and river flows.

Over time, as development throughout the Klang Valley and Selangor has increased, many of these natural ponds have been in-filled, others have been modified to act as storm water retention basins and very few remain in a more or less natural state.

All the ponds surveyed in March 2019 have been modified to a varying extent. In most cases natural flooding cycles and hydrological linkages have been removed or reduced. In addition, hydrological infrastructure such as in-flow and out-flow sluices, gross pollution traps and other drainage structures have been built.

No doubt some of the ponds have also been dredged and drained post-development due to excessive levels of sedimentation, and some ponds, such as the "natural looking" Elmina East Pond 4 will be significantly impacted once land clearance and development commence in adjacent areas.

Maintenance and management of wetlands at Elmina City will ensure that existing biodiversity is maintained and to encourage new species to colonize the sites. Such management will require a comprehensive understanding of the post-development hydrological status of each site. In most cases in tropical, urban wetlands, reduced water flows and exchange of water between water bodies leads to high nutrient loading and ultimately eutrophic water bodies – something that should be avoided at all costs, especially in an urban setting. Hydrological management will therefore be an important consideration within an overall management and maintenance strategy and plan for the site.

Lack of reliable data creates a challenge in determining how an urban wetland interacts with the adjacent watershed. Developing a hydrological model that can describe the urban wetland is an important first step in the successful establishment or reestablishment of sustainable wetlands. It can also be used as a predictive tool for wetland management.

Recommendation 1: Develop a hydrological model for all the wetlands and rivers within the Elmina City development. This should include (but not be restricted to) a) details of water flows and volumes, b) seasonality, c) connectivity and flows between ponds, d) optimal residence periods within individual water bodies, e) nutrient loading, g) flora and fauna

Recommendation 2: Ensure that hydrological management is a part of the Standard Operating Procedures under the Wetlands Management and Maintenance Plan (see Recommendation 13, below).

Improve wetland ecosystem and diversity

Urban wetlands require significant inputs to make them more attractive for wildlife during the post-development phase. Many of the sites will be more or less cleared during development and sites require time and effort (management) to either be restored to a previous habitat type, or developed into new habitat types. In many cases, urban wetlands are also isolated and disconnected from other similar habitats from which species can in-migrate. In the case of Elmina City, there is some connectivity between sites via the Sungai Subang floodplain corridor, as well as close proximity to the Bukit Cherakah Forest Reserve, although most of the wetlands will be / have been cleared during the development and require some effort to restore, re-create and develop habitats and species further.

Recommendation 3: Enrichment planting of suitable tree and shrub species along the Sungai Subang floodplain corridor to create a dispersal corridor for wildlife.

Efforts have been made to plant some native, riverine species throughout the floodplain, but a more targeted approach to planting is required. This will include (but not be limited to) the following: a) an assessment of tree species suitability (target native, lowland riverine tree species with fruiting and flowering resources that are useful for wildlife; b) spacing and mixing of planting areas to create near-natural vegetation zones and mixed species woodland; c) emphasis on species that can withstand long periods of inundation, and have root systems to bind soils and prevent planted matter from being washed away during storm water events.

Table 6: List of recommended plant species for the riverine zone

Fringing marsh/swamp zone (0 – 0.3m above normal water level)

Botanical name	**Common/Local name**
Alocasia macrorrhiza	Elephant's ear
Alstonia spathulata	Marsh pulai; pulai paya
Commelina nudiflora	Common spiderwort; rumput aur
Crinum asiaticum	Spider lily; Bakong
Cyperus halpan	Sheathed flatsedge; para air
Cyperus digitatus	Finger flatsedge; rumput musang
Cyperus compactus	Swamp mariscus; para-para
Shorea longifolia	Meranti hitam paya
Dillenia suffruiticosa	Simpoh air
Eleocharis variegata	Spike rush; purun
Eugenia longifollia	Common kelat
Eriocaulon longifolium	Asiatic pipewort; Rumput butang
Fimbristylis miliacea	Rumput tahi kerbau
Ludwigia octovalvis	Shrubby water primrose; Lakum air
Pandanus immersus	Pandanus; rasau
Ploiarium alternifolium	Cicada tree; riang riang
Shorea platycarpa	Light red meranti; meranti paya
Polygonum barbatum	Knot grass; Panji-panji
Rhynchospora corymbosa	Golden beak sedge; rumput sendayan
Saraca thaipingiensis	Gapis
Artocarpus altilis	Breadfruit; Sukun
Cyrtostachys lakka	Red-sealing was palm; pinang raja
Melaleuca leucadendron	Paper-bark tree; gelam
Pometia pinnata	Langsir
Sindora coriaceae	Sepetir licin

Swamp forest (0.3 – 1.5m above normal water level

Botanical name	**Common/Local name**
Alstonia spathulata	Marsh pulai; pulai paya
Artocarpus heterophyllus	Jackfruit; nangka
Caryota mitis	Fish-tail palm; Tukas
Centella asiatica	Indian pennywort; Pegaga
Commeline nudiflora	Common spiderwort; rumput aur
Cerbera odollam	Yellow-eyed cerbera; pong-pong;buta-buta
Cratoxylon arborescens	Geronggong
Dillenia suffructicosa	Simpoh air
Santiria rubiginosa	Kedondong
Elaeocarpus nitidus	Walnut oil fruit; pinang punai
Eugenia aquea	Water apple; jambu ayer
Eugenia longifolia	Kelat
Ficus benjamina	Beringin
Ficus microcarpa	Malayan banyan; jejawi
Flagellaria indica	Rotan dini
Garcinia mangostana	Mangosteen; semetah

Hibiscus tiliaceus	Sea hibiscus; bebaru
Saraca thaipingiensis	Gapis
Ixora javanica	Javanese Ixora
Ixora umbellate	Malayan white Ixora
Lansium domesticum	Langsat
Licuala spinosa	Palas
Litsea teysmanni	Medang kelor
Melaleuca cajuputi	Paper-bark tree; gelam
Nepenthes gracilis	Slender pitcher plant; periuk kera
Pomentia pinnata	langsir
Shorea parvifolia	Meranti bunga

Recommendation 4: Develop enrichment planting plans for all wetlands within the site, this should include the elements outlined in Recommendation 3 above, as well as enabling natural vegetation regeneration patterns to develop. Enrichment planting should be done in a phased approach.

As mentioned previously, majority of the waterbodies in the CoE is designed with the concept of a manicured garden. Like all constructed ponds, the edges of the ponds are often cut off with artificial edging instead of a gradual flow into the water (**Figure 35**). The steep slope will result in scouring over a period of time leading to erosion and sedimentation. Besides that, the lack of an intermittent zone between land and water will make it difficult for wetland plants to establish.

For wetland plants to establish naturally, it is possible to extend the edge of the pond by adding some substrate thus creating a gradual slope. Another possibility is by enrichment planting where selected wetland vegetation is planted at strategic parts of the ponds to facilitate macrophyte growth.

Figure 35: Difference in slope edge (see red line).

Table 7: List of recommended plant species for the macrophyte zone

Zone 1: Shallow marsh (0 – 0.3 m)

Botanical name	**Common/Local name**
Eleocharis variegata	Spike rush; Purun
Eriocaulon longifolium	Asiatic pipewort; Rumput butang
Fimbristylis globulosa	Rumput sadang
Fimbristylis miliacea	Rumput tahi kerbau
Hanguana malayana	Common hanguana; Bakong
Ludwigia adscendens	Floating Malayan willow; Water primrose; Inai pasir
Ludwigia octovalvis	Shrubby water primrose; Lakum air
Monochoria hastate	Arrowleaf pondweed; Keladi agas
Phylidrum lanugisonum	Fan grass; Rumput kipas
Polygonum barbatum	Knot grass; Panji-panji
Rhynchospora corymbosa	Golden beak sedge; Rumput sendayan
Saccharum spontaneum	Swamp sugar cane; Tebrau
Scleria sumatrensis	Sumatran scleria; Rumput kumba

Zone 2: Marsh (0.3 – 0.6 m)

Botanical name	**Common/Local name**
Eleocharis dulcis	Spike rush; Ubi puron
Fuirena umbrellata	Hairy blue sedge; Rumput kelulut
Lepironia articulata	Tube sedge; Purun; Kercut
Phyllidrum lanuginosum	Fan grass; Rumput kipas
Scirpus grossus	Greater club rush; Rumput kumbar
Scirpus mucronatus	Upright club rush; Rumput bulat
Scleria sumatrensis	Sumatran scleria; Rumput kumba
Typha angustifolia	Cat-tail; Lembang
Typha latifolia	Bulrush; Banat

Zone 3: Deep marsh (0.6 – 1.0 m)

Botanical name	**Common/Local name**
Cyperus compactus	Swamp mariscus; Para-para
Cyperus digitatus	Finger flatsedge; Rumput musang
Cyperus halpan	Sheathed flatsedge; Para air
Lepironia articulate	Tube sedge; Purun; Kercut
Nelumbo nucifera	Sacred lotus; Seroja India
Nymphae nouchali	Star lotus; Teratai putih hutan
Phragmites karka	Common reed; Rumput gedabong
Scirpus grossus	Greater club rush; Rumput kumbar
Scirpus mucronatus	Upright club rush; Rumput bulat
Typha angustifolia	Cat-tail; Lembang
Typha latifolia	Bulrush; Banat

Recommendation 5: Systematic removal and management of alien, invasive tree species such as the two *Acacia* species present at the site. This should be managed using a phased approach to vegetation management and enrichment planting. Special attention should be given to Pond 4 to ensure that the biodiversity and landscape is retained.
Recommendation 6: Ensure that vegetation management and enrichment planting is a major part of the Standard Operating Procedures under the Wetlands Management and Maintenance Plan (see Recommendation 13, below).

Improve fauna diversity

To improve the overall wetland ecosystem and diversity, it is important that Sime Darby and the residents of CoE understand that nature needs to be left wild. For a wetland ecosystem to function and thrive, some parts of the constructed waterbody will need to be left alone for native species to establish. One way of doing so is to emulate the characteristics of natural wetlands.

Maintaining current levels of biodiversity (with a focus on birds and Odonata) within the Elmina City site will be challenging post development. This is mainly due to the fact that many of the wetlands will be severely compromised during the development process – existing vegetation will be cleared, top soils will be removed and graded, ponds will become severely silted, water quality will deteriorate, etc. In other cases, wetlands will be created in areas where wetlands did not previously exist.

In order to improve fauna diversity within the CoE with regards to the waterbodies, naturalization of the ponds is the first step to increasing biodiversity. When the conditions are suitable, it will attract various insects or invertebrates, which in turn attracts larger fauna like amphibians or fishes. The presence of larger fauna will continue to attract larger animals such as mammals and birds who are predators at the top of the food chain. Eventually a self-supporting ecosystem will develop within the CoE waterbodies.

In newly restored wetlands that were previously wetlands, soil seed banks of naturally occurring plant species will be available post development, and it can be expected that improvements in wetland biological diversity at these sites will be faster than at new wetlands where the soil seed bank is lacking. Attracting birds back into the wetlands will require some degree of effort. These will include suitable habitat creation and water level management (creating variable depth ponds with corresponding water depths and vegetation types), as well as planting of species to attract birds (native species of fruiting and flowering trees and shrubs), possible re-stocking of suitable fish prey species, etc. Levels of disturbance and control over public access to some areas will also need to be monitored to prevent over-disturbance.

Besides that, it is possible to establish microhabitats within each pond area to help attract a variety of species to the area. Islands may be installed at strategic locations on the waterbody to provide roosting sites specifically for waterbirds species.

It may also be possible to attract colonial nesting bird species such as grey heron (*Ardea cineria*), black-crowned night-heron (*Nycticorax nycticorax*) and painted stork (*Mycteris leucocephala*) into the site, if the right breeding conditions can be created. These species are nesting at nearby sites with the Klang Valley and at Taman Wetlands in Putrajaya.

Table 8: List of recommended fish species to be introduced in lacustrine habitat

Scientific name	Common name	Local name
Barbonymus schwanefeldii	Tinfoil barb	Ikan lampam
Barbonymus gonionotus	Jawa barb	Lampam Jawa
Cyclocheilichthys apogon	Beardless bard	Chemperas
Esomus malayensis/metallicus	Malayan flying barb	-
Parachela oxygastroides	Glass barb	Ikan lalang
Puntigrus tetrazona	Tiger barb	Pelampong jaring
Rasbora trilineata	Scissortail rasbora	Ikan seluang
Clarias batrachus	Walking catfish	Ikan keli
Aplocheilus panchax	Blue panchax	Kepala timah
Parambassis siamensis	Siamese glassfish	Ikan seriding
Pristolepsis grooti	Malayan leaf-fish	Ikan patong
Anabas testudineus	Climbing perch	Ikan puyu
Helostoma temminckii	Kissing gourami	Ikan tembakang
Betta imbellis	Crescent betta	Ikan belaga
Osphronemus goramy	Giant gourami	Ikan kaloi
Trichopodius trichopterus	3-spot gourami	Ikan sepat
Trichopsis vittata	Croaking gourami	Ikan karim
Osteochilus sp.	Cyprinids	Ikan terbul
Channa striata	Striped snakehead	Ikan aruan

Species to Avoid

These species will need to be avoided at all cost as they are very aggressive and will reduce or destroy the local diversity:

1. Peacock bass (many species) – large cichlids, currently a game fish species in Malaysia
2. African catfish (*Clarias gariepinus*)
3. All Tilapia (cichlid species from Africa & South America)

Recommendation 7: Adopt a regular monitoring procedure to monitor populations of birds and Odonata using simple pictorial guides (**Figure 36**) at the various wetlands during and post development. This will enable the effectiveness of the wetland and habitat restoration and creation to be assessed against the March 2019 baseline, and also provide important data for updating of future management and maintenance plans.

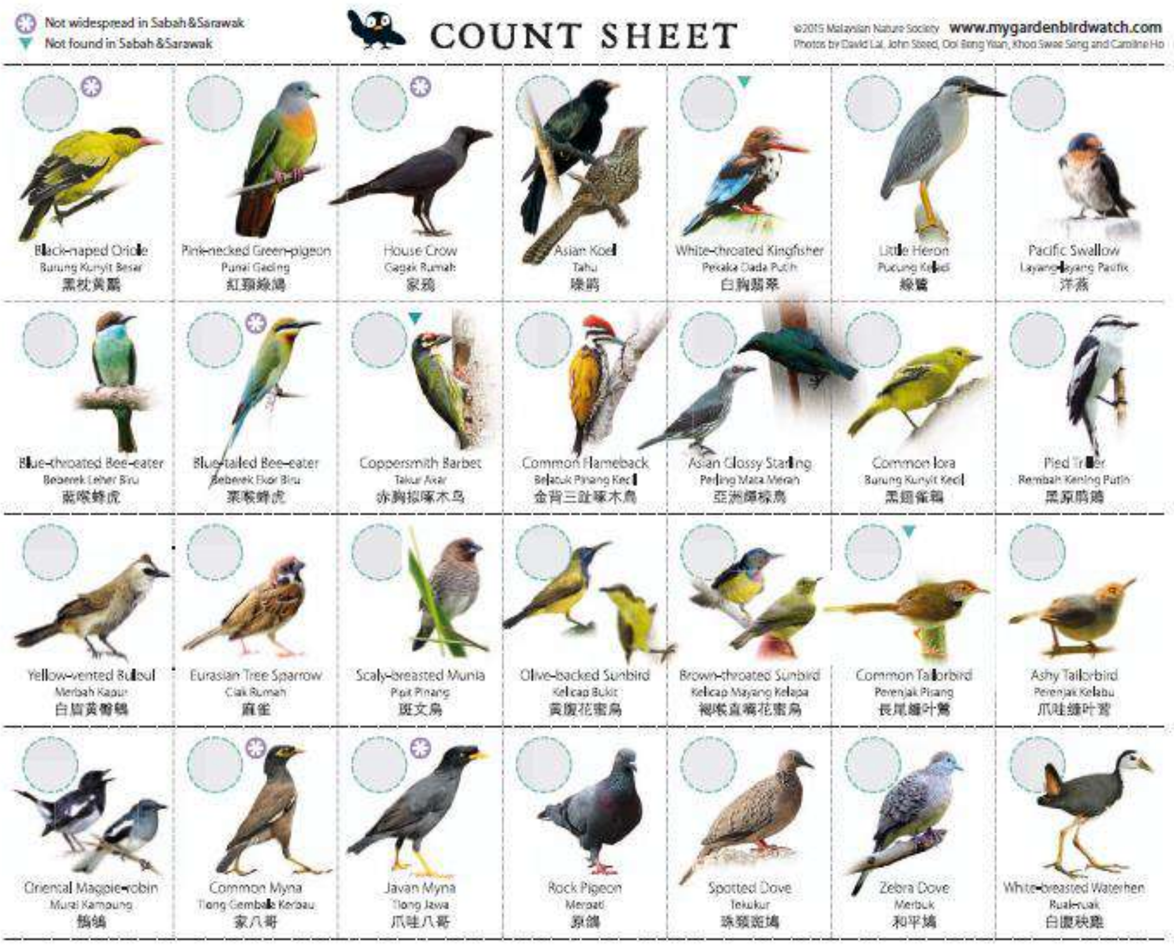

Figure 36: Example of bird observation sheet (Source:MNS).

Potential for community participation in wetland management and monitoring

The maintenance of urban wetland environments and the wildlife they support is an important management issue for developers and local councils. In so many cases, wetlands and parks are created but not adequately maintained; wetlands become sinks for pollution, harbor mosquitoes and other harmful insects and are generally considered wasteland areas. In most cases, residents become disillusioned and disappointed by polluted and over grown landscapes and waterways within their neighbourhoods.

It is therefore important that residents and communities have a role to play in the monitoring and management of the wetlands and other environments created within Elmina City.

Create opportunities for community engagement – citizen science/monitoring by resident volunteers

One way to engage the community is to get them involved in the monitoring of the wetlands and the surrounding environment. Having the community involved is a win-win situation for all parties – namely Sime Darby Elmina Development, the residents and the natural environment.

With the community involved, SDED will have another set of eyes and ears to monitor and protect the environment. Besides that, the community will be able to provide input or feedback to Sime Darby Elmina management which may contain useful information or insights which are applicable for future projects. This will build trust and develop good relations between Sime Darby and the community.

For the community, this will help build up interest among the residents as they will develop a sense of belonging and ownership for the natural environment. Beyond that, they will also be able to foster good relationships between other community members and maybe develop a sense of camaraderie which will benefit the neighbourhood. With the community caring for the environment, it will help the natural environment to establish and stabilize into a healthy and functional ecosystem. The benefits of a healthy environment will ultimately return to the communities who have helped cared for it thus improving the quality of life for the residents of CoE.

Urban wetlands provide opportunities to develop community participation in their management and maintenance to create an environment of ownership and caring amongst residents. Traditionally these are restricted to community involvement through activities such as clean ups (gotong royong). However, the environment at Elmina City provides opportunities to create more value-added community participation mechanisms. Foremost amongst these could be the development of resident action groups to provide inputs and ideas to the Wetland and Landscape Management and Maintenance Operations Manual (see Recommendation 13), and in time the actual implementation of the SoPs through volunteer activities and groups. Additionally, community bird watching groups and wetland monitoring groups can be developed to provide much of the data on biodiversity improvements at the sites.

There are many successful models of resident and community participation in wetland management and monitoring from many countries. These may be “river watch” or “stream watch” programmes under resident associations and volunteer groups; schools oriented projects to monitor streams and ponds; community bird watch programmes; involvement of the community in setting management targets and goals for the sites, etc. The CSR opportunities for Sime Darby at Elmina City will provide a showcase for future development and management of urban wetlands.

Recommendation 8: Develop a strong community-driven culture to involve local residents in management and monitoring of the wetlands. Form a resident association or a wetland monitoring society within the City of Elmina.

Recommendation 9: Enhance safety features around the waterbodies via community volunteering

The CoE is designed to encourage its residents to spend time outdoors and to maintain an active lifestyle; hence numerous waterbodies have been designed within the development to provide a site for recreational activities. As noted earlier, most of the constructed wetlands have steep slopes which could pose as danger for young children who might be playing around the area.

It is proposed that warning signs are set up around the waterbodies to inform parents to be watchful of their children. An alternative would be to install some plants along the immediate edges to restrict residents from going too close to the edge of the pond.

Other safety features could include having floatation devices like life rings in areas where the waters are deeper as a precaution and in case of emergency.

Potential for Environmental Education within the City of Elmina

Urban wetlands and associated habitats provide good opportunities for environmental education and awareness raising of residents and community groups. Wetlands, and the biodiversity they support, are often easily accessible; easy to observe and identify; and, have interesting life histories and stories.

Create opportunities for environmental education

Residents of CoE are blessed to be living in close proximity to the Forest Reserve. Based on the proposed development, with the right environmental conditions created, it is foreseen that some species might spill over from the forest reserve into the development.

While this may seem positive to nature lovers, not everyone will appreciate the thought of having wildlife running around their backyard. Hence, there is a need to engage with the community as it is an opportunity to provide environmental education to the general public and instill a sense of understanding and co-existence between humans and wildlife.

To do so, we may incorporate information signage at strategic locations where residents are most likely to encounter wildlife. The signage may contain information that is educational, informative, notice or warning signs. By incorporating informative signage around the wetlands, we will be able to generate awareness and interest among public users who visit the wetlands.

Provision of simple EE related infrastructure such as board walks, information signage and viewing areas will benefit local residents and communities. Involvement of local school groups in monitoring and research, and ultimately management and clean-up activities will also foster ownership and environmental stewardship and learning opportunities. SDED can promote their green CSR initiatives for Elmina City through development of information booklets and guides to the wildlife of Elmina City; through appropriate signage and infrastructure and through active campaigns to both support EE within the community and to involve locals in management and protection of the wetlands.

Urban wetlands, if managed correctly, can provide an importance educational resource for local residents and schools. As development proceeds, these sites will become premium resources within the Elmina City development.

Recommendation 10: Develop a series of simple guidebooks and leaflets explaining the biodiversity of the Elmina City wetlands – this can start with guides to the common birds and dragonflies, and expand to cover the common plants, butterflies, reptiles, etc.

Recommendation 11: Develop suitable educational signage and infrastructure in areas of public access around the wetlands to inform residents of the significance of the wetlands and the necessary ecological management of these sites.

Recommendation 12: Develop an Elmina City school environmental network that enables pupils and teachers to interact with the wetlands, and build events and activities on wetlands into their respective curricula.

Other recommendations

Management and Maintenance of the Elmina City Wetlands

Long term management and maintenance of the created and restored wetlands at Elmina City will be an essential commitment to ensure sustainability of the development and ensure long term satisfaction of residents. From an ecological perspective, the wetlands will be in a state of constant change, and in order to keep the desired equilibrium, the wetlands will require management and maintenance. For instance, vegetation succession will take place over time, and trees and shrubs that have been planted and introduced to the site may be naturally replaced by other species, or dominated by alien invasive species. The Elmina City management authority will need to decide which "ecological state" is the optimal for the site. In most cases, the optimal site will be determined by a number of indicators or factors that determine wetland health. For example, a) maintenance of water quality standard suitable for recreational activities (not a eutrophic, green algal pond), b) abundance of target bird and Odonata species that indicates a healthy ecosystem, c) reduced number of pests such as mosquito larvae, if the natural ecological balance has been achieved, etc.

Recommendation 13: Prior to handover of Elmina City from the developer (Sime Darby Elmina Development) to the local council (Majlis Perbandaran) a comprehensive "Wetland and Landscape Management and Maintenance Operations Manual" is developed and agreed.

The Wetland and Landscape Management and Maintenance Operations Manual will include provision for Standard Operating Procedures (SoPs) for a) wetland and vegetation management; b) hydrological flow regulation and requirements; c) public access and activities; d) de-silting and dredging requirements; e) supplementary planting and stocking of wetlands; f) water quality and wetlands monitoring, etc.

Recommendation 14: Ensure that a phased approach to vegetation removal and land clearance is taken at Elmina East Pond 4, to ensure that existing levels of biodiversity can be maintained to recolonize the post development wetlands.

Recommendation 15: Adopt a native species planting policy for all landscape enhancements, ensure that no non-native and potentially invasive species are introduced to the site.

Recommendation 16: Adopt and enforce a strict policy of no hunting and fishing during all phases of the development and post development. Incidences of foreign laborers hunting waterbirds and fishing in the ponds during March 2019 may have led to lower levels of biodiversity than could be expected (eg. the complete absence of white-breasted waterhen (*Amaurornis phoenicurus*), a common species that is easily and widely hunted throughout Indonesia and SE Asia.

Next steps

Refine guidelines for wetland design

Wetlands are dynamic ecosystems. Too little is known about wetland creation especially wetlands in tropical countries where there has been limited research on the said topic. There are too many variables involved to predict the outcome and success of any given constructed wetlands. It will require a multidisciplinary approach and expertise from different backgrounds to be involved in the planning and management of the constructed wetlands.

Clear and concise site specific goals should be established at the start of the project to be used in design, monitoring and follow-up. Goals are dependent on circumstance and also intended functions of the constructed wetlands. Though the design of the wetlands is determined by the goals established, there are limitations to this based on current site conditions. Wetlands International will provide a range of guidelines for wetland design which SDED may use for reference in future developments.

Refine draft guidelines for wetlands operation and maintenance

Healthy wetlands are natural ecosystems that require minimal maintenance efforts once they are established ecosystem. However, in the early stages of wetland creation, they will require some form of care and maintenance until the plants are mature and established.

The guidelines will highlight key elements of management and maintenance which are crucial to the establishment and function of healthy wetland ecosystems.

Develop a report card for wetland health assessment

During the previous meeting, SDED requested that Wetlands International provide a checklist of species which they will use for to assess the wetlands health of CoE. This is not possible due to a number of factors: 1) too many methods for assessing wetlands health and too many variables involved 2) different vegetation will form under different environmental conditions which in turn influences fauna 3) CoE wetlands are man-made, most of the vegetation is designed and installed rather than natural establishment hence there is no pre-existing conditions that can serve as a baseline.

It is proposed that a report card is developed instead to help in assessing the health of CoE's wetlands. The report card will include pictorial guides for biodiversity such as birds and odonata. It will also include guides on invasive species. The report card will also include water quality indicators. By combining all the physical and biological indicators, we will be able to develop a system to measure the health of the wetland.

This report card serves two purposes: 1) provide an overview of the health of each individual wetland and 2) engage community participation in the monitoring and protection of the wetlands.

Conclusion

This report aims to provide an overview of the status of CoE waterbodies from a wetland ecologist perspective. It also aims to highlight issues which may arise and provide recommendations which may be beneficial for the development of CoE and the natural environment in the long run though many of the suggestions is still up for discussion.

There are two main types of freshwater wetlands located within the Elmina City development – rivers and their floodplains; and ponds or small lakes.

The Sungai Subang runs through much of the middle of the development in a South-West to North-East direction. Its floodplain forms a wetland corridor through Elmina City. Over time, the floodplain has been straightened, modified and embanked, in order to modify water flows and control flooding along this sector. However, the floodplain still maintains its basic function as a flood inundation zone and water storage and release mechanism along the length of the river. Associated with the floodplain are numerous small ponds and lakes – some of these may be of natural origin, and others may have been excavated more recently as flood water retention ponds and run-off retention ponds. All of these ponds have now been modified (deepened, extended, isolated, etc) to some extent; and, in the case of all the ponds visited in March 2019, the natural hydrological patterns of flooding and inundation, from the river to the ponds and vice versa, have been modified through construction of sluice gates and other water control structures.

A tributary of the Sungai Damansara flows southwards through the western part of Elmina City and joins the Sungai Damansara to the south, which then flows along the southern edge of the development in an eastwards direction. The development of floodplain features along the Sungai Damansara are not as distinct as in the Sungai Subang, and the ponds in Denai Alam are modified drainage features along the tributaries flowing into this river.

The status of the water quality in the wetlands is variable. The Sungai Subang and Sungai Damansara are likely to be nutrient rich due to urban run-off throughout their catchments, and are also probably oxygen depleted during times of low water. Levels of turbidity and suspended sediments are high (visually), with water a typical brownish muddy coloration with low transparency.

In the various ponds, water status is also variable, with those ponds directly linked to the rivers likely to be also nutrient rich and turbid, in some ponds excessive growth of algae and water plants indicates high nutrient loading and in some cases eutrophic status (e.g. Denai Alam Pond B). In most of these ponds levels of land and vegetation clearance within the immediate catchment was high,leading to excessive sedimentation and turbidity. The exception to this is Pond 4 in Elmina East that contained clear water with little suspended sediment, probably due to its wooded catchment, no obvious connection to the Sungai Subang and lack of recent development around its periphery.

In March 12019, levels of biodiversity were generally low throughout the Elmina City wetlands. This is expected within a newly developed housing area, where land and vegetation clearance, hydrological modification of the wetlands, generally high disturbance levels and isolation of remaining pockets of habitats are high.

The most diverse and interesting site within Elmina City in March 2019 was Elmina East Pond 4. This site has the lowest levels of disturbance within the site, and development of adjacent areas has yet to have a major impact on remaining habitats and waterbodies. This has led to development of a quite mature secondary woodland fringe and good water quality. Once development gets underway at this site, most of the habitats are likely to be either destroyed or severely impacted and a phased approach to development will enable species to persist and re-colonize new habitats created.

Elmina East Pond 4 also provides a suitable “benchmark” against which other ponds within Elmina City can be restored and managed.

In conclusion, the wetlands of CoE are considered to be in fairly good condition from a constructed wetlands perspective. Each pond has its own set of good and bad but nothing serious that cannot be fixed. Some minor enhancement activities can be carried out to make it better.

Despite the waterbodies not having high diversity in terms of vegetation, there have been some interesting finds especially in terms of Odonata species.

At this point, priority should be given to Pond B of Denai Alam where algae removal activities need to take place to prevent the further spread of algae to other parts of the waterways.

Design consideration will need to be taken into account for Pond 2 due to abovementioned issues of maintenance access and potential hydraulic short-circuiting.

There is also need for further discussions on how to proceed for Pond 4 of Elmina East and Pond 10 of Elmina West on minimizing construction impacts at these sites as these two ponds show the highest potential for maintaining the naturalness of the wetlands.

With given time and effort, it is believed that CoE will be able to achieve its goal of creating healthy and functioning wetlands that will serve its purpose of providing its residents with a place of well living.

Annex I

Checklist of Avifauna recorded at Elmina City in March 2019, showing their Category and Status in Peninsular Malaysia; IUCN Conservation Status, CITES Appendix listing and legal Status in Peninsular Malaysia.

No.	Vernacular Name	Scientific Name	Category	Status	IUCN Listing	CITES Listing	Legal Status in PM
1	Lesser Whistling-Duck	*Dendrocygna javanica*	A	R	LC		TP
2	Red Junglefowl	*Gallus gallus*	A	R	LC		P
3	Yellow Bittern	*Ixobrychus sinensis*	A	R,M	LC		TP
4	Purple Heron	*Ardea purpurea*	A	R,M	LC		TP
5	Little Egret	*Egretta garzetta*	A	R,M	LC		TP
6	Striated Heron	*Butorides striata*	A	R,M	LC		
7	Crested Serpent-Eagle	*Spilornis cheela*	A	R	LC	II	TP
8	Black-shouldered Kite	*Elanus caeruleus*	A	R	LC	II	TP
9	Changeable Hawk-Eagle	*Nisaetus limnaeetus*	A	R	LC	II	TP
10	Brahminy Kite	*Haliastur indus*	A	R	LC	II	TP
11	Red-wattled Lapwing	*Vanellus indicus*	A	R	LC		TP
12	Pin-tailed Snipe	*Gallinago stenura*	A	M	LC		TP
13	Common Sandpiper	*Actitis hypoleucos*	A	M	LC		TP
14	Spotted Dove	*Streptopelia chinensis*	A	R	LC		
15	Zebra Dove	*Geopelia striata*	A	R	LC		
16	Pink-necked Pigeon	*Treron vernans*	A	R	LC		P
17	Greater Coucal	*Centropus sinensis*	A	R	LC		TP
18	Asian Koel	*Eudynamys scolopaceus*	A	R,M	LC		TP
19	Little Bronze-Cuckoo	*Chrysococcyx minutillus*	A	R	LC		TP
20	Large-tailed Nightjar	*Caprimulgus macrurus*	A	R	LC		TP
21	Swiftlet sp.	*Aerodramus* sp.	A	R	LC		
22	White-throated Kingfisher	*Halcyon smyrnensis*	A	R	LC		TP
23	Blue-tailed Bee-eater	*Merops philippinus*	A	R,M	LC		TP
24	Dollarbird	*Eurystomus orientalis*	A	R,M	LC		TP
25	Coppersmith Barbet	*Psilopogon haemacephalus*	A	R	LC		TP
26	Common Flameback	*Dinopium javanense*	A	R	LC		TP
27	Golden-bellied Gerygone	*Gerygone sulphurea*	A	R	LC		TP
28	Common Iora	*Aegithina tiphia*	A	R	LC		TP
29	Brown Shrike	*Lanius cristatus*	A	M	LC		TP
30	Black-naped Oriole	*Oriolus chinensis*	A	R,M	LC		TP
31	House Crow	*Corvus splendens*	C	F	LC		
32	Barn Swallow	*Hirundo rustica*	A	M	LC		TP
33	Pacific Swallow	*Hirundo tahitica*	A	R	LC		TP
34	Yellow-vented Bulbul	*Pycnonotus goiavier*	A	R	LC		
35	Common Tailorbird	*Orthotomus sutorius*	A	R	LC		TP
36	Ashy Tailorbird	*Orthotomus ruficeps*	A	R	LC		TP

No.	Vernacular Name	Scientific Name	Category	Status	IUCN Listing	CITES Listing	Legal Status in PM
37	Yellow-bellied Prinia	*Prinia flaviventris*	A	R	LC		TP
38	Oriental Magpie-Robin	*Copsychus saularis*	A	R	LC		P
39	Asian Glossy Starling	*Aplonis panayensis*	A	R	LC		
40	Common Myna	*Acridotheres tristis*	A	R	LC		
41	Javan Myna	*Acridotheres javanicus*	C	F	LC		
42	Great Myna	*Acridotheres grandis*	C	F	LC		
43	Plain-throated Sunbird	*Anthreptes malacensis*	A	R	LC		TP
44	Olive-backed Sunbird	*Cinnyris jugularis*	A	R	LC		TP
45	Paddyfield Pipit	*Anthus rufulus*	A	R	LC		TP
46	Eurasian Tree Sparrow	*Passer montanus*	A	R	LC		
47	Baya Weaver	*Ploceus philippinus*	A	R	LC		P
48	Scaly-breasted Munia	*Lonchura punctulata*	A	R	LC		P

Notes:

Category: A = naturally occurring in West Malaysia; C = introduced into West Malaysia (alien species).

Status: R = Resident breeding species; Migrant (visiting) species; F = Feral species

IUCN Listing: Conservation status as defined by IUCN, LC = Least Concern

CITES Listing: Status in Trade, as defined by CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) Appendices. II = Appendix 2, species that may become endangered through excessive trade and require monitoring.

Legal Status in Peninsular Malaysia: as defined by the Wildlife Conservation Act 2010, TP = Totally Protected by Law; p = permit required to hunt / trap

Annex II

Checklist of Odonata recorded at Elmina City in March 2019, showing their locality and IUCN Conservation Status in Peninsular Malaysia.

Odonata observed at City of Elmina. IUCN status: LC = least concern.

	ZYGOPTERA (Damselflies)	Locality	ICUN Status
	Family Coenagrionidae		
1	*Agriocnemis femina* (Brauer, 1868)	Native	LC
2	*Ceriagrion cerinorubellum* (Brauer, 1865)	Native	LC
3	*Ischnura senegalensis* (Rambur, 1842)	Native	LC
4	*Pseudagrion microcephalum* (Rambur, 1942)	Native	LC
	Family Lestidae		
5	*Lestes praemorsus decipien*s (Kirby, 1893)	Native	LC
	ANISOPTERA (Dragonflies)		
	Family Libellulidae		
6	*Acisoma panorpoides* (Rambur, 1842)	Native	LC
7	*Brachydiplax chalybea* (Brauer, 1868)	Native	LC
8	*Brachythemis contaminata* (Fabricius, 1793)	Native	LC
9	*Diplacodes nebulosa* (Fabricius, 1793)	Native	LC
10	*Diplacodes trivialis* (Rambur, 1842)	Native	LC
11	*Crocothemis servilia* (Drury, 1770)	Native	LC
12	*Neurothemis fluctuans* (Fabricius, 1793)	Native	LC
13	*Neurothemis tullia* (Drury, 1773)	Native	LC
14	*Orthetrum sabina* (Drury, 1770)	Native	LC
15	Pantala flavescens (Fabricius, 1798)	Native	LC
16	*Potamarcha congener* (Rambur, 1842)	Native	LC
17	*Rhodothemis rufa* (Rambur, 1842)	Native	LC
18	*Rhyothemis phyllis* (Sulzer, 1776)	Native	LC
19	*Tholymis tillarga* (Fabricius, 1798)	Native	LC
20	*Trithemis pallidinervis* (Kirby, 1889)	Native	LC

Part 02: Design and Management Guidelines for the Constructed Wetlands in the City of Elmina

Habitat Establishment and Biodiversity Enhancement at the City of Elmina

Design and Management Guidelines for the Constructed Wetlands in the City of Elmina

Habitat Establishment and Biodiversity Enhancement at the City of Elmina

For:

Sime Darby Property

Prepared by:

Wetlands International

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Wetlands International wishes to thank Sime Darby Property (City of Elmina) Sdn Bhd for giving us this opportunity to be part of a township development which aims to strike a balance between modern amenities and green living.

Disclaimer

This document provides detailed guidelines to wetland designers, landscape architects and consultants in understanding the requirements for constructed wetland systems within the development of City of Elmina. It is meant to serve as guidance for those who are involved in designing, constructing and managing the constructed wetlands and water bodies within the City of Elmina. Each site needs to be assessed based on its own characteristics including topography, catchment area, predicted storm water flows, and many other criteria to achieve the best solution possible, taking into consideration the current surrounding natural environment and proposed development.

Abbreviation

CEC	Cation exchange capacity
CoE	City of Elmina
EC	Electrical conductivity
FDPM	Forestry Department Peninsular Malaysia
FELDA	Federal Land Development Authority
GCE	Guthrie Corridor Expressway
GPT	Gross pollutant trap
IPM	Integrated Pest Management
NAHRIM	National Hydraulic Research Institute Malaysia
NWL	Normal water level
SF	Surface flow wetlands
SSF	Sub-surface flow wetlands
TED	Top of extended detention
WL	Water level
WQI	Water Quality Index

1.0 Project Background

The City of Elmina (CoE) is an initiative by Sime Darby Property (City of Elmina) Sdn Bhd which covers an area of 5,000 acres of land and water bodies. The said project is being developed for residential, commercial, industrial, public amenities, infrastructure/utilities, open space and detention pond areas.

City of Elmina is located within the former Sime Darby Plantations agricultural land under oil palm production, and the area is located between the Subang and Sungai Buloh districts in Selangor. The development is accessible via the Guthrie Corridor Expressway (GCE) which runs through the site. The area is also situated adjacent to the Bukit Cherakah Forest Reserve and a reservoir catchment forest, one of the few remaining patches of tropical lowland rainforests remaining in the State of Selangor.

The term Bukit Cherakah Forest Reserve is used to depict the forest adjacent to the development in Elmina West. According to the Forestry Department Peninsular Malaysia (FDPM), the forest reserve adjacent to the CoE development was previously made up of a larger forest reserve area known as the Sungai Buloh Forest Reserve. In the 1990s, parts of the Sungai Buloh Forest Reserve were opened up for development by Federal Land Development Authority (FELDA) although there was no official degazettement of the forest reserve. Subsequently in the early 2000s, the Forestry Department carried out a survey, demarcated the new boundary and renamed the forest reserve as Bukit Cherakah Forest Reserve.

The vision of Sime Darby Property in the development of the City of Elmina has been to "embody wellness and embrace the art of living well". The development forms an important component of the Selangor Vision City - the township that is the catalyst for growth in the Guthrie Corridor. As such, Sime Darby Property has incorporated extensive green spaces as well as public spaces into this development. These include parks and gardens, a wellness hub, and up to 90km of cycling and jogging tracks. As wetlands form an important component within the City of Elmina, Sime Darby Property engaged the expertise of Wetlands International Malaysia to provide guidelines on the design and management of the constructed wetlands and to provide recommendations for the biodiversity enhancement at these constructed wetlands.

1.1. Goal

The goal of this guideline is to assist and guide Sime Darby Property (City of Elmina) Sdn Bhd in developing, managing and sustaining the wetlands in the City of Elmina to ensure they remain ecologically healthy and thriving as enhanced habitats for a balanced biodiversity thus demonstrating the Best Practices for future housing developments and sustainable community.

1.2. Objectives

- To develop guidelines for wetland design and management guidelines for healthy constructed wetlands; and
- To produce a checklist to be used as a reference for designing to achieve class 'A' standards for healthy constructed wetlands.

2.0 Introduction

2.1. What are wetlands?

The Ramsar Convention on Wetlands (Ramsar, 1971) defines many types of wetlands found around the globe, and encourages member states to manage their wetlands sustainably. Malaysia has ratified the Convention in 1997.

Under the text of the Convention (Article 1.1.), wetlands are defined as:
"Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres".

Thus, wetlands have a broad definition to include lakes, rivers, underground aquifers, swamps and marshes, peatlands, tidal flats, mangroves, coastal areas and all man-made sites such as fish ponds, paddy fields and constructed wetlands. This includes natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or saline.

Every wetland is a unique actualization of many abiotic and biotic factors, including geologic and geomorphic history, topography, connections to the local and regional hydrological system, connections to local and regional ecosystems, time since formation, and disturbance history. Wetlands, rivers and lakes play an integral role in human well-being. These ecosystems provide a wide range of services that bring about social, cultural, economic and environmental outcomes for the community. Some of the benefits provided by wetlands include water supply and purification, natural resources, and coastal protection.

Box 1: Wetlands or wastelands?

In the past, there has been little appreciation for wetland environments due to the poor understanding of their values in the perspectives of economic contribution, functions and the ecosystem services they provide. Traditionally perceived as 'swamps' or wastelands, the term 'wetland' conjures images of hostile environments with brackish water, mosquitoes where access are generally thought to be difficult. These traditional attitude and perception have resulted in a widespread disregard for wetland environments leading to the active conversion of wetlands. Until today, drainage, dredging, land-filling, agriculture, water contamination, erosion, clearing, fires are still threatening the remaining wetlands of our country and will continue to remain a threat. In many instances, housing and property developments have sought to in-fill and destroy wetlands within their development sites for these reasons. However, developers have increasingly recognised and acknowledged the importance and value of maintaining wetlands within new development zones to provide recreational, visual and functional aspects for both human communities and local wildlife.

Under the Ramsar Classification of Wetland types, wetlands can be grouped into three categories: Marine and Coastal Wetlands, Inland Wetlands and Man-made Wetlands. Overall, there are 42 different types of wetlands, of which 31 types can be found in Malaysia (**Table 9**).

Table 9: Ramsar classification of Wetland Types.

Ramsar Classification of Wetlands Type		
Marine and Coastal Wetlands • Marine water (permanent shallow waters less than six metres deep at low tide, sea bays, straits) • Subtidal aquatic beds, seagrass, seaweed beds • Coral reefs • Rocky shores including rocky offshore islands, sea cliffs • Sandy beaches • Estuarine waters • Intertidal mud and sand flats • Coastal, riverine and brackish water mangrove swamps • Lagoons	Inland Wetlands • Seasonal and irregular rivers and streams • Riverine floodplains, includes flooded river basins, seasonally flooded grassland • Permanent freshwater lakes, includes large oxbow lakes • Seasonal freshwater lakes, floodplain lakes • Permanent freshwater ponds (> 8 ha) • Seasonal freshwater ponds • Marshland • Freshwater swamp and swamp forests, seasonally flooded forests • Peat swamp forests • Nipah forests • Melaleuca forests • Other swamps, sago swamps, riparian swamps, woodland swamps • Freshwater springs	Man-made Wetlands • Water storage areas, reservoirs, barrages, hydro-electric dams • Aquaculture ponds, fish ponds, shrimp ponds • Excavations, mining pools • Wastewater treatment, sewage farms, settling ponds, oxidation ponds • Irrigated land and irrigation channels, rice field, canals, ditches • Other ponds, farm ponds, ash ponds, stock ponds • Constructed marshland, pond and lakes • Constructed saline lakes

2.2. Why are wetlands important?

Wetlands are vital for human survival. Being some of the world's most productive environments, they provide support not only to humans but also to countless species of flora and fauna for their survival. The numerous benefits or rather ecosystem services they provide to communities is key in our rapid development and growth. Wetland functions and benefits are largely divided into four categories as described in **Figure 37**.

Figure 37: Benefits and functions of wetlands

In a urban development plan it would be prudent to include the feature of constructed wetlands as its functions will ensure the environmental sustainability of the project. The natural functions of constructed wetlands within the City of Elmina development needs to be fully understood prior to planning for infrastructure and other development of the site. Many aspects need to be taken into consideration, amongst others – the direction of the natural hydrological flows, the volume of water within the desired development landscape, the retention periods within ponds, floodplain features, and flood risk reduction, the efficiency of flow and drainage system within the landscapes.

Apart from that, riverine corridors and wetlands buffer zones are equally important in the design consideration, especially in terms of wetland habitat establishment and biodiversity enhancement. This is because the riverine corridors and wetlands buffer zones will enable the re-colonisation of sites through in-migration of fauna species and flora seeds. Besides, these areas would reduce the in-flows and sedimentation of water courses over the long-term. Less sediment in water courses leads to better and faster drainage and reduction of flood risk – all critical for urban planning.

2.3. The role of constructed wetlands in development

In urban setting, wetlands serve a function by enhance greater biodiversity, natural and pleasant recreation areas for city residents. Apart from that, wetlands are created to buffer the run-off from precipitation and slow down the draining rate. This is an environmentally friendly approach compared with rapid drainage system using concrete drains and pipes. These created wetlands or constructed wetlands are man-made systems which contain vegetated water bodies that use sedimentation, fine filtration and biological uptake processes to remove pollutants. They are designed to emulate the functions and processes of natural wetland for various benefits and purposes.

In some circumstances, people refer constructed wetland as urban wetland since it appears in urban areas often. Constructed wetlands and urban wetlands share many similarities including the ecosystem services provided. The only trait which can distinguish them clearly is where they are located; constructed wetlands can be located at any area but urban wetlands only found in urban area (**Table 10**). As a rule of thumb, constructed wetland is a man-made wetland system, while urban wetland is any wetland that present in urban setting.

Table 10: The comparison of constructed wetlands and urban wetlands.

Description	Constructed Wetlands	Urban Wetlands
Nature		
Natural		√
Man-made/ engineered	√	√
Location/ setting		
Urban	√	√
Rural	√	
Anywhere	√	
Direct functions		
Flow regulation	√	√
Flood control	√	√
Prevent saltwater intrusion	√	√
Transportation	√	√
Recreation	√	√
Tourism	√	√
Research	√	√
Education	√	√
Ecological functions		
Sediment retention	√	√
Nutrient retention	√	√
Toxin removal	√	√
Micro-climate stabilisation	√	√
Wetland benefits		

Description	Constructed Wetlands	Urban Wetlands
Water supply	√	√
Biodiversity resources	√	√
Forage resources	√	√
Agricultural resources	√	√
Energy resources	√	√
Attributes		
Biodiversity gene bank	√	√
Heritage preservation	√	√
Carbon sink	√	√
Example	• Recreational park in CoE	• Putrajaya Wetlands (man-made)
		• Mangrove forest along Port Dickson coast (natural)

About half of the world's population live in urban areas today. The rapid growing urban populations has posed an enormous challenge for city planner, managers and developers as they have to ensure that cities today can deliver not only basic services such as accommodation, transport, water and amenities; but that these cities are safe, resilient, sustainable and environmentally friendly.

Constructed wetlands provide a buffer between developed and natural systems, and in developments such as City of Elmina, they provide a critical function to prevent pollution and siltation of aesthetic water features such as the Central Park lake system.

Malaysia is a global leader in constructed wetlands and was one of the first countries to include constructed wetlands as part of a major urban development. In the late 1990s, the development of the new administrative capital of Putrajaya included a series of constructed wetlands to ensure that run-off and urban drainage from the development of Putrajaya would not pollute and sediment the central lake feature of the development (Figure 2). Wetlands International Malaysia was responsible for detailing the design criteria, reviewing of tender documents and technical review and oversight during the construction and management of the wetlands. At that time, the Putrajaya constructed wetlands were the largest constructed wetland system in the World.

The four principal purposes of constructed wetlands as identified by Kadlec and Knight (1996) are:

a) To compensate for and help offset the rate of loss of natural wetlands as a result of agriculture and urban development (constructed habitat wetlands)
b) To improve water quality (constructed treatment wetlands)
c) To provide flood control (constructed flood control wetlands) and
d) Food production (constructed aquaculture wetlands)

Constructed wetlands have become increasingly popular in recent years for the second purpose identified above; i.e. to treat urban storm water and to remove contaminants that would be potentially detrimental to the receiving water ecosystem.

Multiple use constructed wetlands, which combine a number of purposes and benefits, are becoming more common in urban settings. Wong et al (1999) list the following purposes and benefits which are commonly combined:

a) Flood protection
b) Flow attenuation
c) Water quality improvement
d) Landscape
e) Recreational amenity
f) Provision of wildlife habitat

Box 2: Putrajaya Wetlands

Putrajaya Wetland, the first well designed constructed wetland in Malaysia was built in 1997 in the valley of Chuau and Bisa Rivers, in an area of what was formerly an oil palm plantation named Ladang Perang Besar. The wetland covers an area of 650 ha including the huge spectacular Putrajaya Lake with its associated marshes and 24 wetland cells. These interconnected wetland cells are planted with various macrophytes such as *Phragmites karka, Eleocharis dulcis, Thpha angustifolia, Fimbristylis globulosa and Scirpus grossus*. The wetlands vegetation act as filter to trap sediments and other suspended solids and absorbs excess toxicants and nutrients. The Putrajaya Wetland is home to macrophytes, birds, amphibian, reptiles, small mammals and invertebrates. In order to enhance the biodiversity within the wetland ecosystem, the authority had released approximately 24 species of fish into the wetland cells and lakes. The self-sustaining and balanced lake ecosystem is crucial in maintaining the water quality of the lake and the development of Putrajaya as a "City in the Garden".

Figure 38: The Putrajaya City represents the coming of age of Malaysia as an advanced member of the global community committed to the Sustainable Development Goal 11 – Sustainable Cities and Communities.

A major consideration in the use of constructed wetlands for storm water management is to replace, to some degree, the wetlands that have already been lost. Wetlands are nature's natural "kidney" system and the loss of this filtering function of wetlands can be correlated, at least in part, with the decline in the quality of our water resources systems.

Protecting existing wetlands, in conjunction with increasing the total extent of wetlands through wetlands restoration, creation, or construction for new developments forms part of an effective strategy for downstream aquatic resource protection.

2.4. Types of constructed wetlands

Constructed wetland generally, consists of an inlet zone (sedimentation basin to remove coarse sediments), deep pools, macrophyte zone (vegetated area to remove fine particulates and uptake soluble pollutants) and a high flow bypass channel (to protect the macrophyte zone from scour and vegetation damage). The main elements of a general constructed wetland system are shown in **Figure 39**.

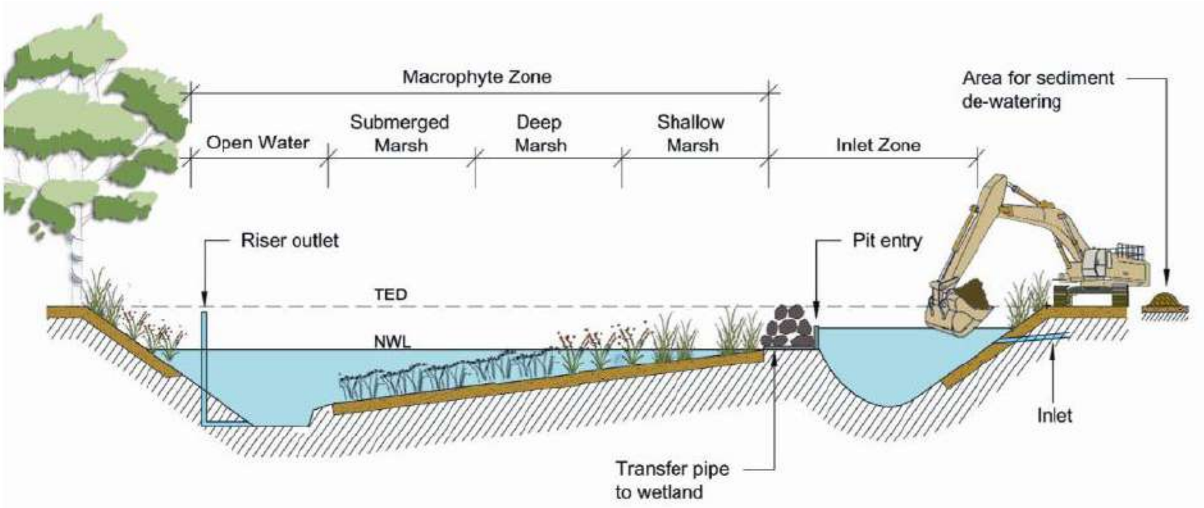


Figure 39: Elements of a general constructed wetland. (Source: Adapted from WSUD Engineering Procedure)

Constructed wetlands can deliver different functions according to needs. Treatment wetlands are designed to remove excessive and harmful pollutants from wastewater as well as storm water runoff. On the other hand, enhancement wetlands are designed with the intention of not only creating an environment suitable for recreational and environmental education activities but also, to treat wastewater. Both types of wetland systems can be designed as separate systems or they can be incorporated into a single design with multiple treatment and enhancement objectives. Constructed wetlands in general are classified as either surface flow wetlands (SF) or subsurface flow wetlands (SSF).

2.4.1. Surface flow wetlands (SF)

Surface flow wetland is a wetland where water flowing through the system and is exposed to the atmosphere (**Figure 40**). Surface flow wetlands resemble natural wetlands in the way it looks and the way it treats wastewater. It is a shallow wetland which uses the combination of emergent wetland plants (cattail, bulrush and reeds), floating plants (Asian water-grass and white primrose) and submergent wetland plants (water trumpet) to treat wastewater (Figure 41). These systems can eventually exhibit interesting aquatic ecology, attracting various fauna and creating an environment that can be converted into parks suitable for recreational purposes.

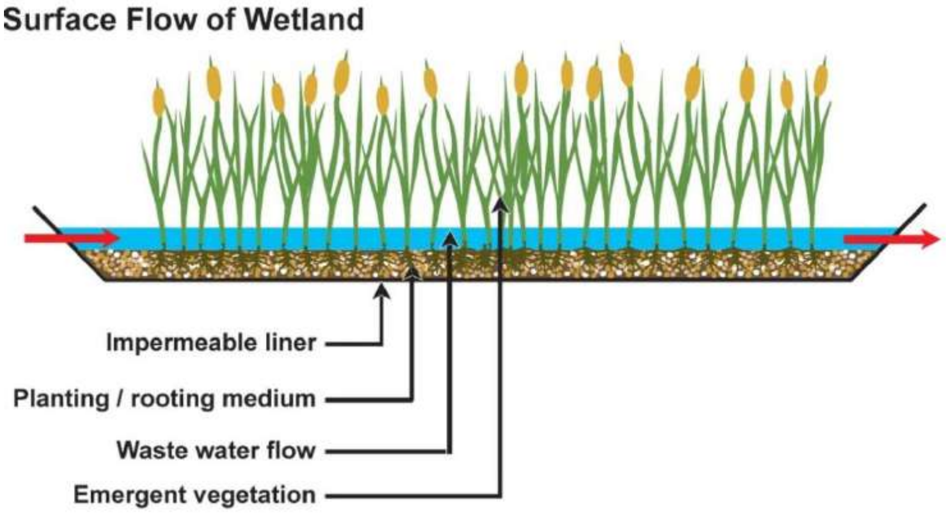


Figure 40: A sketch of a surface flow wetland. (Source: Constructed Wetlands Q&A, 2013)

Figure 41: The surface flow constructed wetland with wetland plants to take up excessive nutrient at Putrajaya Wetlands. (Source: Wetlands International – Putrajaya Wetlands cells)

2.4.2. Subsurface flow wetlands

Subsurface flow wetlands consist of a gravel bed with emergent wetland plants growing in them (Figure 42). Wastewater flows through the gravel bed but does not rise above the surface. Roots and rhizomes of the plants grow into pore spaces in the gravel (**Figure 43**). They allow microorganisms to break down biodegradable material through the decomposition process. The plants also absorb metals and harmful nutrients in wastewater. These areas are almost mosquito and odour free as water flows beneath the surface area.

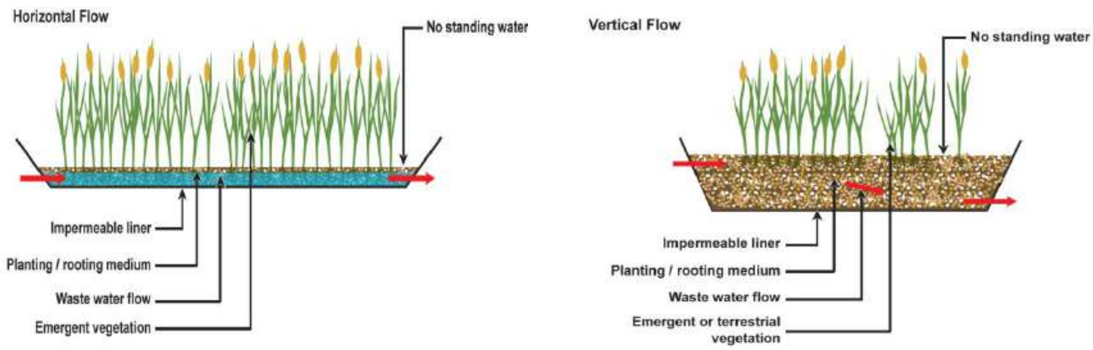


Figure 42: The sketch of horizontal and vertical subsurface flow wetlands. (Source: Constructed Wetlands Q&A)

Figure 43: The horizontal sub-surface flow constructed wetlands where the water flows through the plants' roots and soil bed but does not rise above the soil surface. (Source: Wetlands International – the experimental plot at NAHRIM)

3.0 Design Procedures and Considerations for Constructed Wetlands

3.1. Design procedures

Designing a constructed wetland entails following steps:

a) Goals and objectives for creating the said wetland,
b) Site suitability in terms of hydrology (i.e.: the source of water and the direction of flow),
c) Suitability of the present soils to support permeability and vegetation growth, and
d) Design of the constructed wetlands and take into consideration other related issues such as public safety and maintenance.

The design process has three distinct components: Design Intent, Functional Design and Detailed Design.

3.1.1. Design intent

Besides improving storm water quality, constructed wetlands can support other urban design and conservation objectives. These additional aspects should be documented in the Design Intent. It is a critical component that guides the design of a constructed wetland. It should also describe the treatment performance required by the wetland, local flora and fauna protection or enhancement objectives, landscaping objectives and recreational use objectives. The Design Intent should be created in consultation with all key stakeholders and needs to be undertaken before the functional design.

Constructed wetlands may be designed to meet many different objectives:

a) Water quality enhancement
b) Water storage and flood attenuation
c) Groundwater recharge
d) Primary production and food web support design
e) Human uses – aesthetic, recreational, commercial, educational

3.1.2. Functional design

A Functional Design addresses the issues identified in the Design Intent and demonstrates an understanding of the wetland performance objectives and basic design principles.

3.1.3. Detailed design

The Detailed Design of the wetland outlines the specifications of the works associated with the wetland and upon approval will be used for the wetland construction.

The following steps are recommended for designing wetlands:

a) Confirm treatment performance of concept design
b) Determine design flows
c) Design the inlet zone
d) Design the macrophyte zone
e) Design open water zone outlet

f) Design embankment, spillway and high flow bypass channel
g) Specify vegetation
h) Consider maintenance requirements
i) Design calculation summary

3.2. Design considerations and requirements

Due to different climatic conditions, the design considerations of each constructed wetlands may vary. The following design considerations and criteria outlined in this document are to be used as a guideline and are intended to address key requirements such as maintaining wetland vegetation during the dry season, managing weeds and providing natural means of managing mosquito populations for the constructed wetlands within the City of Elmina.

Poorly designed and/or maintained wetlands are unlikely to gain community support. Hence, it is essential to address potential issues such as pests and weeds at the conceptual design and continue the implementation along with long-term maintenance through community education and awareness as community acceptance towards the constructed wetlands will be driven by their aesthetics and landscape amenity value. The importance of the 'long-term' management must be emphasised throughout the community education and awareness programmes, then executed on the ground through the collective effort of the community.

The operation of constructed wetlands involves the interaction between storm water runoff, vegetation and hydraulic structures. However, successful implementation of constructed wetlands requires appropriate integration into the landscape design. Specific designs vary considerably depending on site constraints and preference of the designers and community. Several features to be incorporated into the wetland design are elaborated in the following sub-sections.

3.2.1. Site selection

Surface and ground water hydrology are the most important considerations in selecting a constructed wetland site. Without the correct hydrology, the wetland would not be able to serve its purpose and it may be necessary to consider alternate sites after conducting groundwater monitoring.

The wetland creation should minimize impacts to upland habitat and buffers. If possible, utilize wetland or upland areas that were previously degraded.

Locate the constructed wetlands in an area that is contiguous to other wetlands, buffers, open space or undisturbed areas to increase wildlife habitat potential. The constructed wetland should blend in with the natural landscape.

Sun exposure should be taken into consideration due to plant specific lighting requirements. Constructed wetlands are located where it can receive all the site runoff, generally at minimum excavation cost. The location of the wetlands should take into account the natural site features that might be used as additional temporary storage areas when the wetlands capacity is exceeded during extreme events.

If the design includes protection of watercourse during floods then the system should not be located a floodplain due to risk that detention storage will be lost through inundation. Flood waters also tend to transport high sediment and debris load which leads to additional wetlands maintenance.

Access for construction and maintenance equipment at the site is required to minimize impact to significant upland and wetland resources.

The minimum surface area of a wetlands should be no less than 1% of the contributing drainage area.

3.2.2. Hydrology

Water level fluctuation is essential in designing wetland elevations and selecting plant species. Sites with complicated hydrology may require monitoring for more than one year, depending on rainfall patterns.

Creating a wetland next to an existing wetland may preclude the need for groundwater monitoring as biological benchmarks may be found in the existing wetland.

Wetlands require a positive water balance through continuous base flow or groundwater seepage to sustain permanently wet conditions.

The soil beneath the wetlands should be sufficiently impermeable to maintain wet conditions unless the wetlands intersect the water table. In permeable soil, a liner is required to prevent drying out.

3.2.3. Slope and stability

Wetlands basin require near zero longitudinal slope. Wetlands should not be sited on unstable ground and ground stability assessment is required. Wetlands should not be considered within or over waste fill materials, uncontrolled or non-engineered fill.

3.2.4. Construction consideration

A supervisor should be present to oversee wetland construction. Ideally the individual, whom had designed the constructed wetland, evaluated groundwater hydrology and selected wetland plants. Minor modifications may be necessary due to site conditions.

A supervisor should have the flexibility and be encouraged to add habitat structure such as small nesting islands, stumps, logs and small pools (**section 6.0**) as these microhabitats will attract more biodiversity.

The base and edge of the constructed wetlands should be compacted properly before placing the topsoil which is suitable for wetlands planting. The topsoil material should be placed by an excavator to minimize compaction of the soil medium and to promote root growth. Machinery should be prohibited on the ground once topsoil has been placed.

Establishing good wetland vegetation cover quickly is important to reduce the succession of unwanted invasive species.

3.2.5. Monitoring and maintenance

The wetland project, including planting and follow-up maintenance should be integrated to deliver a functional constructed wetland for public or community use.

Plans should specify that the success of the wetland be evaluated to determine if any remedial steps or actions need to be taken to improve its functionality.

Long term maintenance requirements should be clearly defined in the plans.

Maintenance access to constructed wetlands needs to be considered when determining the layout of a wetland system. Access to all areas of the constructed wetlands is required for maintenance. In particular inlet zones and gross pollutant traps (GPT) require a track suitable for heavy machinery to enable the removal of debris and desilting activities.

Macrophyte zones require access to the areas for weeding and replacement as well as regular inspections. These access tracks can be incorporated with walking paths around the wetland system.

3.2.6. Public safety

Constructed wetlands located in housing development may pose a safety risk to the public. Hence, provision should be made for public safety by eliminating, mitigating or minimizing risk so far as is reasonably practicable through:

- Ensuring safe egress from the sediment basin or wetland through batter design.
- Adopt control measures such as fencing or dense planting around identified hazards.
- Adopt warning measures such as signage where appropriate.

Safety risk may include:

- Deep water
- Fast flowing water
- Falls from height

Designers should evaluate all available practicable precautions or controls and designed in the following hierarchy:

Avoid	hydraulic design that minimizes areas of deep and/or fast flowing water
Minimise	design of edge and batter profiles that facilitate public egress from areas with standing water
Mitigate	incorporate appropriate visual and other sensory signals to inform pedestrians, cyclists, parents and children aware of water nearby

Where deemed necessary, fences or dense vegetation barriers to restrict access can be incorporated into wetland areas.

Safety hazards and control measures should continuously be monitored, reviewed and reported throughout the project lifecycle to help provide opportunities for evaluation and continuous improvement.

Besides safety hazards, the design of constructed wetlands will need to take into consideration the prevention of mosquito breeding. Mosquito borne diseases are a serious concern in tropical countries. The pond design will need to minimize the risk that mosquitoes will breed there.

Mosquito control strategies include:

- Management of floating garbage and litter at regular intervals to prevent accumulation and potential for mosquito breeding sites.
- Selection of plants which provide breeding grounds for mosquito predators.
- Introduction and management of fish populations to ensure mosquito larval feeding species are predominant.
- Encourage fish breeding.
- Shaping of ponds to avoid stagnant waters with poor circulation.
- Mechanism to regulate pond levels to disrupt breeding larvae.
- Shaping of pond edges to avoid trapping of water in depressions during changes in pond water level.
- Enhancement of fringing aquatic vegetation to provide suitable habitats for aerial predators (Odonata, bee-eaters, bulbuls, flycatchers, etc.), and underwater mosquito larvae predators such as amphibians, Odonata, diving beetles, etc.).
- Management of water through-flow (to create flowing, not static water conditions) to reduce the potential for mosquitoes to complete breeding cycles.
- Management of water replenishment and water retention periods to reduce the potential for mosquitoes to complete breeding cycles.

4.0 Guidelines for Constructed Wetlands Design

4.1. Wetland level design

When setting wetland water levels, each of the wetland components need to be considered thoroughly for the wetlands to function effectively.

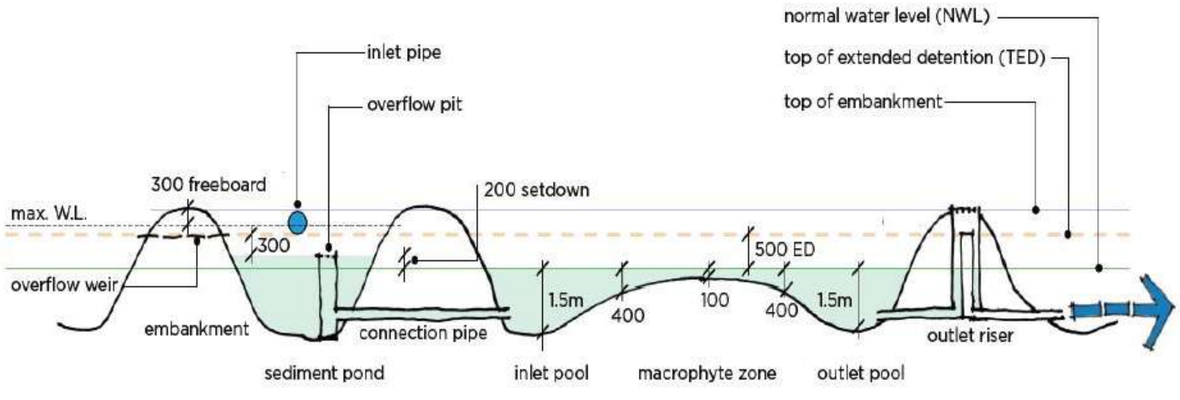


Figure 44: The illustration of different wetland levels. (Source: adapted from Wetlands Design, 2017)

4.1.1. Normal water level

Wetlands should contain a combination of water depths (Figure 44). Water depth in the wetland usually ranges between 0.1 m to 1.5 m. Water levels in excess of 1 m should not occur over more than 20% of the wetlands pond surface area (preferably limit to the inlet and outlet open water zones as deep water supports less plant species).

Depth of temporary storage above permanent water level should not exceed 1.5 m to allow submerged macrophytes to colonize.

4.1.2. Outlet pipe level

Outlet pipe levels must allow the wetland to drain freely to the receiving drainage system. The pipe grade should provide a minimum 0.3% (≥0.5%) so that accumulated sediment does not block the outlet pipe connection with the receiving drainage system.

4.1.3. Extended detention depth

The extended detention depth should be equal or less than 0.5 m depth to prevent damage to wetland vegetation through excessive inundation depth (Figure 45). The selection of plants for different zones of wetlands must be suitable with the water depth as well.

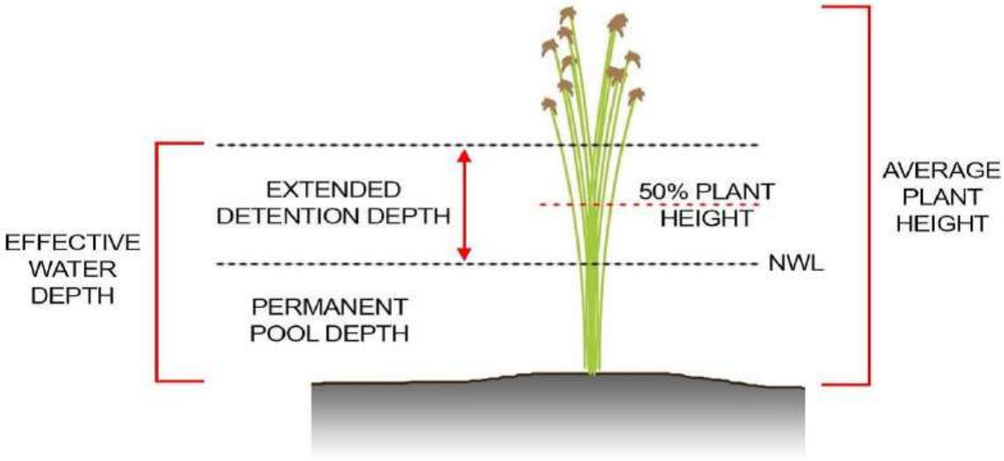


Figure 45: The water depth should not exceed more than 50% of the plant height. (Source: adapted from 'Treatment wetlands – Planning and design', Wetland Info 2018)

4.1.4. Maximum water level

The maximum water level in the wetland will be controlled by the inlet arrangement to the macrophyte zone and the size of the macrophyte overflow weir. The maximum wetland water should be assumed to be 0.3 m above the top water level (Figure 44).

4.1.5. Top of embankment level

The top of embankment needs to be at a consistent level around the entire wetland to ensure that water from the wetland cannot discharge over low points in the embankment (Figure 46). Where constructed wetlands are located within the flood storage, the embankment level may be dictated by flood storage requirements. A low embankment may be constructed around the wetland within the flood storage to protect the wetland from regular flood events.

Figure 46: An example of consistent level for the top embankment level at Pond 10.

Box 3: Important note - Wetland level design

It is important to carefully consider constructed wetland levels early in the design process and to make appropriate allowances for any constraints that may be encountered as the design progresses. Constraints in constructed wetland levels can impact development earthwork levels. Allow for a contingency in preliminary estimates of constructed wetland levels to avoid problems associated with raising development levels late in the design process is recommended as it is generally easier to reduce development levels than to increase them. In situations where the sediment basin extended detention is higher than the macrophyte zone extended detention there will need to be an overflow weir on the macrophyte zone. Where the macrophyte zone and sediment basin have a common top of extended detention, a macrophyte zone overflow may be used to minimise maximum water level and therefore the required height of embankments around the perimeter of the macrophyte zone.

4.2. Wetland layout design

Wetlands play a significant role in storm water management, but they also play an important role in creating urban ecology and community landscapes. The following sub-section outlines some of the design issues that need to be considered when designing the layout of a constructed wetland.

4.2.1. Shape and location

To ensure that the water quality performance of the constructed wetlands is achieved, there are a number of functional layout and shape requirements (Figure 47):

- Sediment basin to be located at the inflow discharge location from the catchment.
- Inflow from sediment basin must enter from one end and exit at the opposite end.
- The end of the macrophyte zone and outlet need to be located as close as possible to the discharge point in the receiving drainage system.
- High flow bypass must connect from the sediment basin high flow bypass weir to the waterway or floodplain.
- Maintenance tracks, embankments and batters must be allowed for when establishing location and space for constructed wetlands.

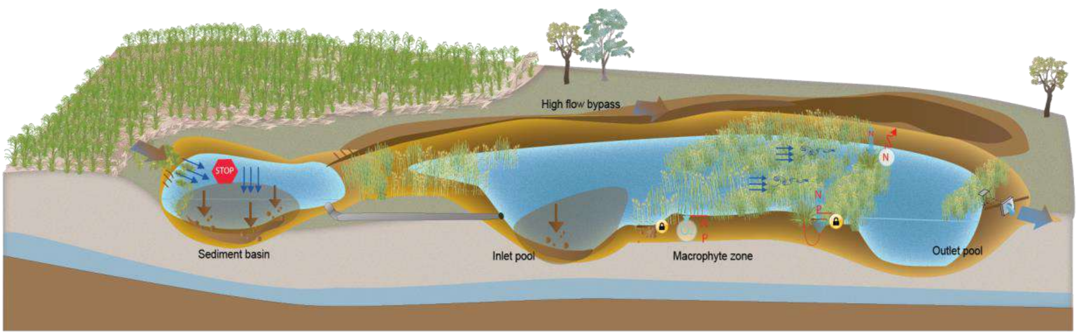


Figure 47: Functional layout and shape requirement. (Source: adapted from 'Treatment wetlands – Planning and design', Wetland Info 2018)

4.2.2. Landscape integration

The shape and location of constructed wetlands must ensure that the system is integrated with the landscape and take into consideration site constraints.

Features surrounding constructed wetlands have an important role in defining the overall shape and edge design of the system. Existing features need to be preserved and are an important constraint to the layout of the wetlands. Features in the surrounding area that will be created or modified will also need to be considered, especially their value to the environment and community. Such features may include:

- Vegetation or trees
- Local topography
- Waterway and associated riparian zone
- Pedestrian paths and/ or roads
- Jogging and/ or cycling track
- Residential areas
- Playgrounds or active parks

4.2.3. Inlet design

The inlet zone comprises of deep open water body (1.5 m to 2.0 m) that operates as a sedimentation basin which has two key functional roles (Figure 48). The primary is to remove coarse to medium sized sediment prior to flows entering the macrophyte zone as this ensures that the vegetation in the macrophyte zone is not smothered by sediments and allow the macrophyte to target finer particulates, nutrients and other pollutants. The second is to control and regulate the flows entering the macrophyte zone and bypass of flows during ‘above design flow’ conditions.

The inlet structure (perforated pipe), if needed, should be laid perpendicular to the direct flow in the wetland pond, this would help to maximise an even flow distribution. The inlet should be designed to minimise the potential of short circuit and clogging in media.

There are a range of issues that should be considered when designing an inlet zone. When available space for constructed wetlands is constrained, it is important to ensure that the size of the inlet zone is not reduced. This is to ensure that the larger sediments are effectively trapped and prevented from smothering the macrophyte zone. If there is constraint on size, then it is the macrophyte zone that should be reduced accordingly.

Large wetland systems would require a GPT as part of the inlet zone to protect the wetlands. Install a GPT at the end of incoming waterway to capture litter and large debris before it enters the open water.

The crest of the overflow pit should be set at the permanent pool level of the inlet zone.

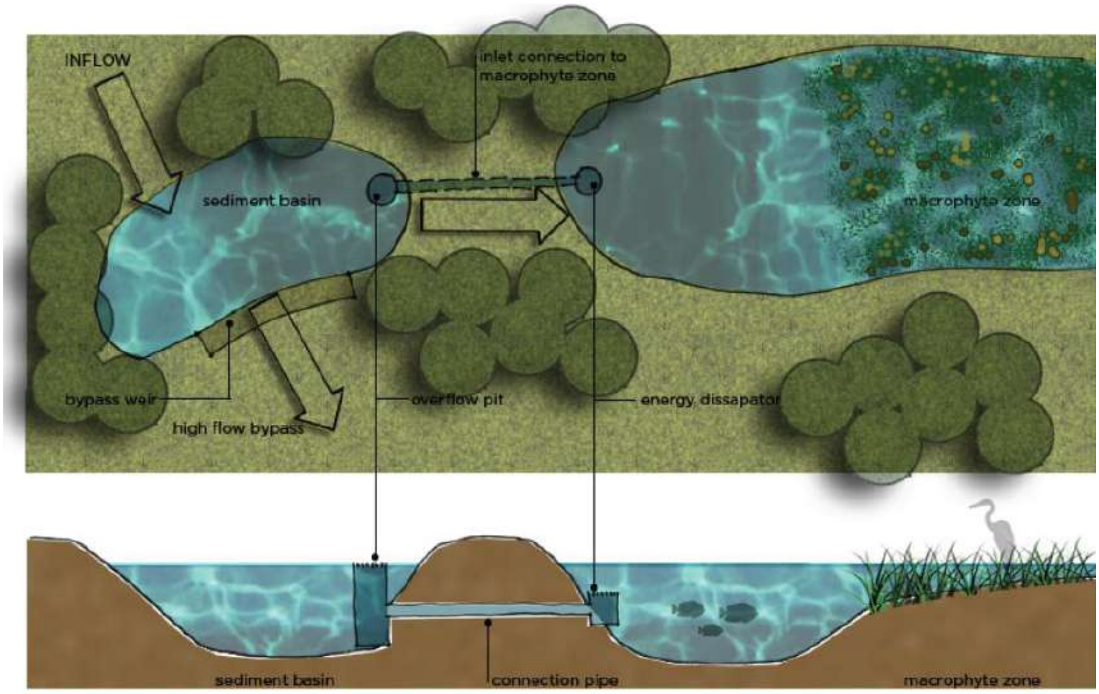


Figure 48: An illustration of the ideal inlet design, outflow pit and the connection to the permanent pool/ macrophyte zone. (Source: Mentari - adapted from Wetlands Design, 2017)

4.2.4. Wetland edge and landscape interface

Dense littoral vegetation around the wetland perimeter is required to avoid the ingress of weeds during the dry season (Figure 49). To maintain littoral vegetation, irrigation is required especially during the dry season. During extended dry periods, wetland macrophytes may also require irrigation to sustain dense foliage and prevent opportunities for weed species.

Provision must be made for draining the macrophyte zone for water level management during plant establishment phase. The macrophyte zone outlet structure needs to be designed to provide a notional detention time for a wide range of flow depths. The outlet structure should also include measures to exclude debris to prevent clogging.

Figure 49: The healthy littoral vegetation around the wetland perimeter at Pond 10.

The interface of a constructed wetlands should be planted with suitable native trees and shrubs species. The planting of terrestrial vegetation can not only prevent soil erosion and slow down the surface run-off, the vegetation can serve as the microhabitats to attract other biodiversity such as tree shrews, squirrels, avifauna and more to the site. The elaboration on habitat enhancement to attract more biodiversity is described in **section 6.0**.

> Box 4: Important note: Wetland layout design
>
> Wetland earthworks should avoid the critical root zone (typically defined as 500 mm beyond the vegetation's drip line) of any retained vegetation (e.g.: trees). Advice should be sought from an arborist regarding earthworks close to trees.

4.3. Sediment forebay design

A sediment basin has two key functions. The primary function is to remove coarse to medium sized sediments prior to flows entering the macrophyte zone to ensure that vegetation is not smothered by coarse sediments. The second function is to control and regulate flows entering the macrophyte zone. In providing this function, the sedimentation basin protects vegetation in the macrophyte zone against scouring during high flows. The sediment basin should be designed to remove at least 90% of the particles with size of ≤ 125 µm.

When the available space for constructed wetland is constrained, it is important to ensure that the size of the sediment basin is not compromised. This ensures the larger sediments are effectively trapped and prevented from smothering the macrophyte zone. On the other hand, if the space for constructed wetland is ample, the size of the macrophyte zone could be extended for a better nutrient uptake.

The overall size of a sediment basin can be determined using the equation below:

$$A = \frac{Q}{V_s}$$

Where
A = surface area of the sediment basin (m^2)
Q = flow rate (m^3/ sec)
V_s = sediment settling velocity (m/ sec) = 0.011 m/ sec (for very fine sand with 125 µm)
[the sediment settling velocity for different particle size is in Table 11]

Table 11: Sediment settling velocity for different particle size.

Classification of particle size range	Particle diameter (µm)	Settling velocity (m/s)
Very coarse sand	2000	0.2
Coarse sand	1000	0.1
Medium sand	500	0.053
Fine sand	250	0.026
Very fine sand	125	0.011
Coarse silt	62	0.0026
Medium silt	31	0.0066
Fine silt	16	0.0018
Very fine silt	8	0.0004
clay	4	0.00011

It is worthwhile to note that the design of the hydraulic connection of the sediment basin to the macrophyte zone (Figure 48 and Figure 50) must deliver a solution which:

- Conveys water up to the design flow from the sediment basin to the macrophyte zone
- Avoids blockage of pipes
- Is accessible by maintenance staff

Figure 50: An example of sediment forebay at Pond 2.

For the constructed wetlands in City of Elmina, it is recommended that the pit is located towards the edge of the sediment basin where it is accessible for maintenance.

Box 5: Important note - Sediment forebay design

It is possible to modify the outlet to facilitate spill containment. This may include baffles around the overflow pit. Reverse grade pipes (with no overflow pit) may also be used to trap pollutants that are lighter than water within the sediment basin. An appropriately sized overflow pit and pipe can provide an outlet for major storm events.

4.4. Macrophyte zone design

Macrophyte zone – soluble and colloidal pollutants are mostly removed by sorption (absorption – 'into' and adsorption – 'onto') to biofilms on stems and roots of wetland plants. Dense vegetation is important for effective treatment and vegetation with large stem surface area provides the greatest treatment. Emergent macrophytes are also important for:

- Oxygen transfer to the sediments to facilitate the processing and immobilizing of pollutants captured and held within wetland sediments.
- Aid in the treatment of nutrient and heavy metal concentrations, either through direct uptake or providing a surface for biofilms and epiphytes that assist with the removal of pollutants.
- Influence sediment deposition and filter sediment particles from the water column.
- Influence hydrology and hydraulics by promoting even flow distribution through the wetland.
- Provide shade, decrease light availability for algal synthesis.
- Decrease erosion by reducing wave action and flow velocities while binding soil particles with their root systems.
- Provide a basis for wetland food chain and supply shelter for mosquito predators such as macro-invertebrates and fish.

Therefore, wetland project should have well defined goals that will influence the scope and strategies to establish vegetation. Common goals in wetlands include:

- Creation of wildlife habitat
- Improve water quality
- Replace lost wetland functions
- Increase diversity of wetland communities
- Soil and water conservation
- Capable of providing aesthetic and passive recreation

The Table 12 summarizes the role of vegetation in a wetland environment.

Table 12: Role of vegetation in constructed wetlands.

Functional Process	Role of Vegetation
Physical	Reduces inflow velocity and protects base from scour and promotes settling of fine sediments from the water column to the wetland bed.
Chemical	Water plants transfer oxygen to the sediments to keep them aerated and facilitate biochemical and microbial processes.
Biological	Pollutants are trapped through adhesion to biofilms or direct uptake by plants. Plant root and stem provide a substrate for microbial growth. Soil microbes facilitate decomposition and mineralization of organic matter, nutrient uptake, nitrogen processing and heavy metal uptake. Root decay provides continuous source of carbon for denitrifying bacteria.
Ecological	Planting design and species selection can be used to recreate local plant communities and enhance local biodiversity.
Aesthetics	Wetland vegetation can be used to create a highlights aesthetic environment that compliments adjacent public open space and enhance passive use of these areas.
Public safety	Vegetation along the edge of the wetland can be used to prevent public access to open water areas in the wetland.

The macrophyte zone is a densely planted basin with shallow pond water and typically has deep open water pools at the inlet and outlet. Besides, it is an area where majority of the nutrient uptake occurs. Hence, constructed wetlands should have a dense cover of healthy, actively growing plants that help to remove pollutants from the stormwater. Detailed design of the macrophyte zone entails the designs described in the following subsection.

4.4.1. Area and layout

Surface area of deep refuge pools within the wetland should be between 20% - 30% of the total macrophyte area. The layout of the macrophyte zone needs to be configured to balance the contact time that water flowing through the system has with the vegetation.

4.4.2. Shape

Design of the macrophyte zone should optimize hydraulic efficiency and avoid dead pockets of water. It is important to avoid short circuit flow paths and poorly mixed regions within the macrophyte zone to optimize wetland performance. The recommended length to width ratio is 4:1 as anything less than this can lead to poor hydrodynamic conditions which reduce water quality treatment performances.

4.4.3. Bathymetry

Bathymetry study is a survey to measure and determine the depth of oceans, seas, lakes and ponds. Wetland bathymetry and vegetation influences the distribution of flows through a wetland hence it should be designed to ensure that 80% coverage of vegetation promote a sequence of marsh and deep marsh zones in addition to small open water zones.

The preferred extended detention depth is 0.5 m, but a deeper extended detention depth of up to 0.75 m may be accepted where the wetland has a high hydrologic effectiveness and where botanic design uses plant species which tolerant to greater depths of inundation.

The macrophyte zone is to have a flat cross-sectional bathymetry only grading up at the edge batters to facilitate the even distribution of flows to avoid short circuiting, create a uniform hydraulic conveyance and maximize storm water contact with macrophyte stems and biofilms.

The bathymetry of the macrophyte zone should be designed to be around 2 m in depth to ensure that a permanent pool of water is sustained throughout the dry season and ensure that habitat is retained for fish, macro-invertebrates and submerged macrophytes.

Longitudinal bathymetry of the macrophyte zone should grade smoothly from 0.7 m in depth up to a central crest 0.5 m in depth and then back down to a maximum of 0.7 m in depth to ensure that isolated pools of water are not created within the macrophyte zone during the dry season when the normal water level slowly draws down due to evapotranspiration.

Particular attention should be given to the placement of the inlet and outlet structures, length to width ratio of the macrophyte zone and flow control features to promote high hydraulic efficiency within the macrophyte zone.

4.4.4. Batters and edge design

Consideration of public safety is important when wetlands are located in public open spaces or easily accessible areas. Reducing public safety risk can be achieved in a number of ways.

One method of reducing risk is to design batter slopes on approaches and immediately under the normal water level (Figure 51). It is recommended to have a gentle slope to the water edge that extends below the water line. Safety requirements for individual wetlands will vary from site and requires careful consideration.

The following rule of thumb can be applied to constructed wetland systems:

- For water depths >150 mm and maximum batter slope of 5:1 (H:V) or less, no fencing is required
- For water depths >150 mm and maximum batter slope greater than 5:1 (H:V), fencing may be required.

Batter design must have minimized safety risks and are stable, minimize maintenance, enhance public safety and integrated to surroundings as to minimize visual impacts. It is recommended that a gentle slope to the water edge and extending below the water line before the slope steepens into deeper areas.

For safety, stability and promoting the growth of macrophytes, slopes should range from 5:1 (H:V) to 8:1 (H:V). Side slopes above water level should also be gentle for safety reasons and limit erosion. A side slope of 10:1 (H:V) to 20:1 (H:V) is recommended for a distance of 5 m from the wetlands edge to allow maintenance access.

In some cases, vertical edges are used for wetlands, therefore a safety fence/barrier should be considered on top of concrete or stone walls where:

- The risk of a serious injury in the event of a fall
- There is high pedestrian or vehicular exposure
- Where water ponds to a depth of greater than 300 mm
- Where water is expected to contain pollutants

The type of fence/barrier to be considered:

- Pool fence in areas where there is a chance of drowning and the surrounding area has small children
- Dense vegetation at least 2 m wide and 1 m high

Figure 51: Steep slope (left) versus gradual slope (right) affects wetland vegetation.

4.4.5. Macrophyes planting zone

A well-designed wetland should consist of a range of vegetation types that:

- Enable wetland performance objectives to be met
- Integrates with the surrounding landscapes
- Suppresses weed growth
- Thrives in local climate
- Enhances local biodiversity

Designing a wetland planting plan to meet these objectives will require consideration of planting set-out (**section 4.4.1**), macrophytes planting zones, species selection (**section 4.4.6** and **Annex 02**), planting density (**section 4.4.7**) and the type of media (**section 4.4.10**) to be applied. Aquatic vegetation selected should be tolerant of fluctuating water levels.

Planting location needs to be determined again after the wetland has been constructed as the wetland creation process may alter ground or surface water hydrology, which would require modifications accordingly in planting locations. Often planned hydrology is different than expected after construction.

The batters of the wetland should be levelled out to ensure no small reservoirs remain that provide breeding habitat for mosquitoes.

Deep marsh and sediment ponds should have a means to isolate and drain under gravity to allow maintenance activities.

A wetland vegetation and weed maintenance program shall be established for a period of at least 24 months after the initial planting of the wetland.

Wetland vegetation is generally divided into three zones – deep marsh, marsh and edge (**Annex 02**). Constructed wetlands must be designed to provide optimal conditions for plant growth to support the treatment process of the wetland (Figure 52).

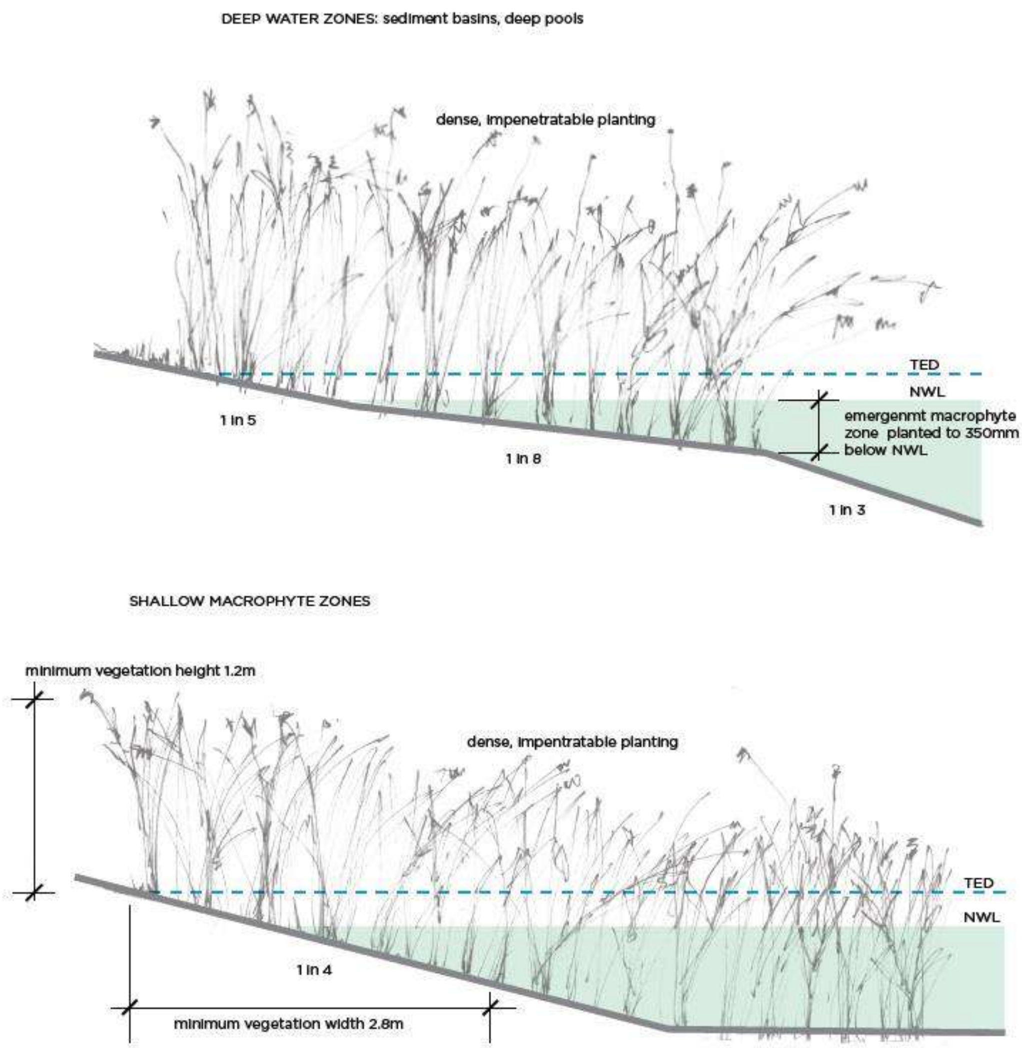


Figure 52: Typical cross section of deep and shallow macrophyte zones in a constructed wetland.

Key plant attributes selected for a constructed wetland includes:

- Planting a <u>diverse range</u> of plant species will ensure higher likelihood of successful plant establishment as well as long term wetland treatment performance and resilience to changing conditions.
- A minimum of <u>one core</u> plant species should be selected for each macrophyte planting zone. A minimum of <u>75%</u> of each macrophyte planting zone should be planted with the core plant species. The remainder of the macrophyte planting zone can be planted with supplementary plant species.
- Plant species have been grouped according to their tolerance to <u>water depth</u>, inundation and plant growth characteristics. The list of plant species according to their tolerance to water depth and inundation is available at Annex 02. While some individual species may have specific tolerances, some species are able to grow across a wide range of depths.
- It is essential that all the elements involved achieve a <u>harmony</u> from the beginning. There are no rules about what should be used when stocking a pond. There is likely to be <u>diversity</u> in all aspects. However, there are some distinct key areas that need attention.

- Submerged plants are the crucial element in achieving success as they perform diverse roles within the water body. They absorb nutrients in the water and provide oxygen to aquatic organisms. Besides that, they are a food source themselves, habitat and nursery for other aquatic life.
- Marginal plants around the pond are very important in bank protection and run-off filtration. It will also have an effect on the overall visual quality of the water garden as well as provide public safety feature.
- Removing excess nutrients in the pond helps to reduce the occurrence of algae.
- The establishment of diverse wetland plant communities is an important component of healthy, functioning wetlands. Successful vegetation establishment requires a thorough assessment of the project site and a well-coordinated approach for project planning, implementation and maintenance.

4.4.6. Macrophytes selection

Natural wetlands have high species diversity. Generally, plants selection would be based on nearby "reference wetland" or natural wetlands as they would provide an indication of which species are suited to local environmental conditions. A preliminary site visit will show which species already exist at the site and may colonize naturally.

Plants selected should be native to the area. Using local species will increase the chances of plant survival and reduce the risk of introducing foreign plants which may affect native flora and fauna.

Planting plan should include a good mix of species. Species selection should be based on the design functions and the water depth of the wetlands. The wetland plants selected should serve multiple purposes such as soil stabilization, nutrient uptake, food and shelter for wildlife.

Once natural hydrology is restored, it is inevitable that wild sources of wetland plants will colonize the system through seed, root and shoot dispersal, and other means. This is not a bad implication, as plants that can grow naturally within the ecological conditions created will always thrive better than species which have been introduced and planted. However, there is a need to ensure that invasive weed species; and, undesirable alien or exotic species do not invade the system.

Generally, the criteria in selecting the suitable macrophytes can be summarised as the list below:

- Select native species
- Likely to establish under conditions
- Unlikely to colonise outside the designated area
- Tolerant to storm water runoffs and pollutants
- High biomass production
- Perennial species
- Rapid growth but avoid invasive species
- Valuable as wildlife habitat
- Broad feasible mixture of plant species to maximize plant diversity enhance stability of the wetland
- Planting zone

4.4.7. Planting density

No more than a third of the pond's surface may be occupied by foliage at any one time. Any excess should be removed regularly and periodically to ensure that sunlight is able to penetrate and reach submerged plants.

A suitable planting density should be used to ensure that at least 80% vegetation cover of the wetland macrophyte zone is achieved after two growing seasons. The planting density required to achieve this varies according to individual species growth characteristics. Planting density should not be uniform for all species as some colonize at faster rates. Individual spacing requirements should be identified for each species. Wetlands are dynamic environments and the vegetation cover can be expected to vary over time in response to disturbance events and natural succession.

Table 13: Recommended planting density.

Zone	Depth Range (m)	Planting Density (plant/m^2)
Ephemeral zone	0 – 0.2m above permanent pool	9
Shallow marsh zone (20% of planting area)	0 – 0.3m below permanent pool	10
Marsh zone (30% of planting area)	0.3 – 0.6m below permanent pool	6
Deep marsh zone (50% of planting area)	0.6 – 1.2m below permanent pool	4

It is recommended that for most species the planting density is based on 9 plants per square meter. However, if rapid plant establishment is required for this project, it is recommended that planting density be increased to 12 plants per square meter in order to increase the establishment rate and reduce the gaps. For *Hanguana malayana* it is recommended that a planting density of 2 - 3 plants per square meter be used as it is a large plant.

Box 6: Planting tips

- Plant in patches/ cluster rather than wider spacing.
- Select plants according to the water depth.
  - E.g. 1: planting zone with water depth of 0 – 0.5 m
    60% Lepironia articulata – marsh (core)
    20% *Scirpus grossus* – marsh (supplement)
    20% *Monochoria hastata* - shallow marsh (supplement)
  - E.g. 2: planting zone with water depth of 0.4 – 1 m
    70% *Phragmites karka* – deep marsh (core)
    20% *Leprironia articulata* – marsh & deep marsh (supplement)
    10% *Scirpus mucronatus* – marsh (supplement)
- Fertilizer is generally not necessary.
- Plants tend to spread faster under saturated soil conditions rather than standing water. However, terrestrial weeds will move in to saturated soils faster than flooded soils. Water level fluctuation (manually) will help spread plants and decrease terrestrial weed establishment.
- Water control is very important during the establishment year.
- Sand bags and portable water pumps can be used to temporarily control the water level during the establishment stage.
- Successful wetland plantings require significant planning and a good understanding of the hydrology of the site.
- Monitoring is essential for successful plant establishment.

4.4.8. Macrophytes zone outlet

The macrophyte zone outlet is a key hydraulic structure in a constructed wetland. The outlet structure serves two purposes:

- Control water levels, flow and volume in the macrophyte zone; and
- Provides a way for draining the wetland for maintenance activities.

Similar to the inlet, attention should be given to the placement of the outlet structures, the length to width ratio of the macrophyte zone and flow control. Water level management of the macrophyte zone during plant establishment phase should also be taken into consideration. The water level is controlled by the outlet structure, which may be a weir, spillway or adjustable riser pipe. Variable height weir such as a box with removable stoplogs will allow the water levels to be adjusted.

Spillways are simple to construct but not adjustable, incorrect water levels can lead to wetland failure and correcting the spillway height may be difficult.

Weirs and spillways should be designed to pass the maximum probable flow and consist of wide cuts in the dike with side slopes no steeper than 2:1 (H:V).
Outlet structures should be designed so that they are easily identifiable for the maintenance crew. It should also require easy and safe access for maintenance and operations personnel.

If the wetland is accessible to the public or vulnerable to vandalism, the outlet structure should be enclosed in a lockable concrete structure or manholes to avoid damage or tampering of the water level settings. This includes protection against damage by wildlife. Measures may include installing covers or wire mesh over the openings, enclosing controls, gauges and monitoring devices in pipes or boxes.

Outlet structures should be designed and located so that they are easily identifiable and maintainable. This requires easy and safe access for maintenance and operational personnel. The ability to have total visibility inside the weir pit through a grate is important. Structures must be protected against damage by animals. Measures include installing covers or wire mesh over openings, and enclosing controls, gauges and monitoring devices in pipes or boxes. To discourage the growth of algae, open water areas near the outlet should be avoided.

4.4.9. Soil

Soil composes of five ingredients — soil organic matter, living organisms, minerals, gas, and water. Soil minerals are divided into three size classes — clay, silt, and sand and the percentages of particles in these size classes are called soil texture (Figure 53).

Soils are indicators of the presence of wetlands where their morphological features were developed in wet environments. Four conditions are required for a soil to become anaerobic and support reducing reactions and the development of soil morphological features. If these chemical transformations occur in the soil's upper layers:

- The soil must be saturated to the point of excluding atmospheric oxygen.
- The soil must contain a source of organic matter that can be oxidised or decomposed.
- The soil must contain a population of respiring microbes that will oxidise the organic matter.
- The water must be stagnant or slow moving.

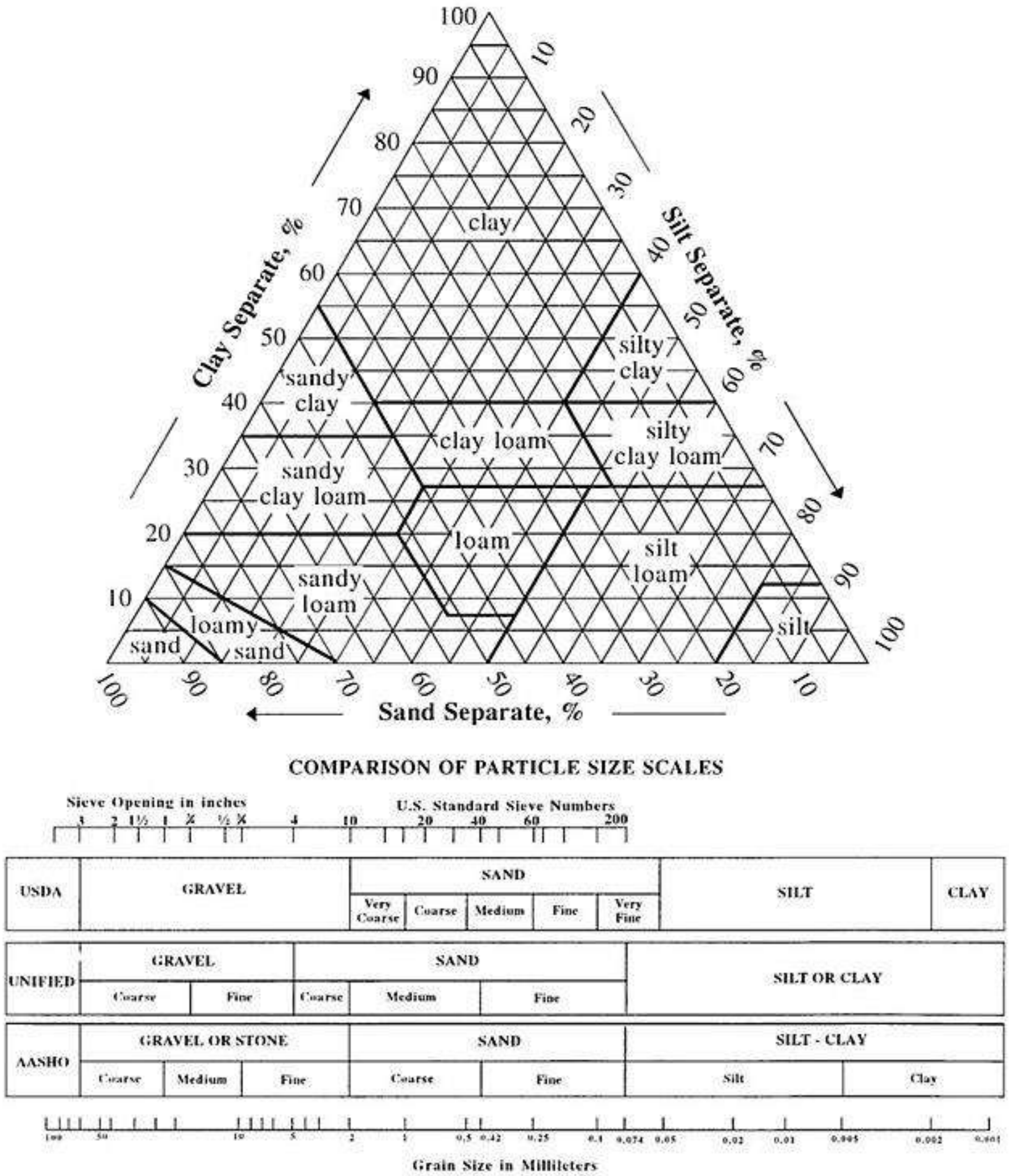


Figure 53: Unified Soil Classification System.

Wetland soils are called hydric soils and are different to the soils found on dry land (Figure 54 and Figure 55). Wetland soils can be identified using soil morphological indicators such as:

- the accumulation of organic matter
- gleyed soil colours
- soil mottling
- iron or manganese segregations
- oxidising root channels and soil pore linings
- reduction of sulphur and carbon (e.g. acid sulfate soils)

Figure 54: Hydric soil with mottling (left) vs upland soil (right).

Figure 55: Example of wetland soils.

Wetland soils has direct impact on other wetland characteristics, e.g. water quality, fauna or vegetation, and can be a reflection of the physical processes occurring in the wetland, e.g. water inflow, water chemistry or filtering of pollutants.

Both soil and hydrology play an important role in the successful establishment of a constructed wetland. Soil properties which need to be considered in selecting soils include cation exchange capacity (CEC), pH, electrical conductivity (EC), texture, soil organic matter, composition, distribution and depth.

Soil pH affects the availability and retention of nutrients and heavy metals. It should measure between 6.5 – 8.5. Electrical conductivity of the soil affects the ability of the plants and microbes to process the waste material flowing through the wetlands.

CEC measures a soil's capacity to hold positively charged ions and varies widely among different soils. The redox potential of the soil is an important factor in the removal of nitrogen and phosphorus.

Soil activity is influenced by the surface area of the soil particles and the electrical charge on the surface of the soil particles.

The soil's capacity to remove contaminants is due to soil-water contact. Sandy or gravelly soils have high porosity and water moves quickly through the soil. Silty or loamy soils which have finer textures promote longer soil-water contact. The flow through well decomposed organic soils and clay is slow. The soil must provide enough organic matter to support microbial activity and plant growth, particularly during the initial establishment stage.

4.4.10. Wetlands construction and soil substrate

Constructed wetlands are designed to retain water. Wetlands which are dependent on overland flow, impermeable soils need to be present at the wetland site and in the watershed for flow to enter and remain within the wetlands basin. If in-situ soils are unsuitable for water retention, a clay liner can be used to ensure that water is available for vegetation. Liner is required if the permeability of the soil is greater than 10^{-6} m/s.

Wetlands which are dependent on a combination of surface and groundwater flow, impermeable soils are often needed in the watershed to channel water into the wetland but where groundwater infiltration occurs - permeable soils, such as sandy loams would be necessary.

Many substrates are suitable for wetland establishment. Medium textured or loamy soils are good because they are soft and friable which allows for easy rhizome and root penetration. These soils have high retention of pollutants and little restriction on plant growth.

Dense soils, such as clays and shales, should be avoided because they may inhibit root penetration, lack nutrients, and have low hydraulic conductivities although such soils may be suitable for wetlands used for nutrient-rich wastewaters such as agricultural and domestic wastewaters.

Sand and gravel are inexpensive alternatives to soil and provides an ideal texture for hand planting as they hold plants well and they have little or no restriction on root growth. Similar to clay and shales, these substrates are suitable for constructed wetlands receiving water high in nutrients, such as domestic and agricultural wastewaters. Adding organic matter will improve plant survival and growth during the first several years while the organic litter is beginning to build up within the wetland. However, these substrates dry out quickly and may need to be irrigated to maintain water levels while the vegetation is becoming established. Coarse textured soils may result in having drier plant communities depending on water level.

In general, most wetland species prefer soil high in organic matter. It is important to know the plant species soil requirements before planting them in the wetlands. Generally, 6"- 12" of appropriate soil medium should be placed in the created wetland to provide a suitable depth for wetland plant establishment.

Box 7: Important note - Macrophyte zone design

A provision of temporary flow diversion during plant establishment should be made to divert water around the macrophyte zone. This can be achieved by blocking the overflow pit connection to the macrophyte zone by using sand bags and portable water pump. Any flows into the sediment basin will then pass over the spillway containment and into the high flow bypass.

4.5. Maintenance access

Wetlands must be designed to facilitate safe maintenance access to all areas of the wetland. Maintenance requirements should be considered through all phases of the wetland design as it may be too late to modify a wetland design to accommodate maintenance access during the detailed design.

Formal access to the wetland is required for heavy machinery and vehicles for sediment basin dredging and general maintenance activities hence suitable point to access the wetlands must be provided (Figure 56). In particular inlet zones and GPT will require a track for heavy machinery to remove debris and de-silting activities.

Figure 56: An example of maintenance access from Pond 2.

To aid maintenance, it is recommended that the inlet zone is constructed with a hard bottom. This is crucial if maintenance involves driving into the basin and plays an important role by allowing excavator operators to detect when they have reached the base of the inlet. Macrophyte zones require access to the areas for weeding and replanting as well as regular inspections. Hence, these tracks are usually incorporated with walking paths around the wetland systems.

Box 8: Important note - Maintenance access

All maintenance access must consider the broader landscape context and ensure that it does not detract from the amenity or result in unacceptable limitations on regular users of any open space. Where possible, maintenance access should be co-located with pedestrian paths to limit the amount of concrete. In situations where the maintenance access track is combined with pedestrian footpaths, the access track is typically 1.5 m wide with a flat vegetated edge of at least 0.5 m either side of footpath. Local authority requirements should be considered when combined footpaths are being considered.

5.0 Construction and Establishment

This section provides general advice for the construction and establishment of the constructed wetlands and key issues which may affect the successful establishment and operation.

Functional installation of constructed wetlands occurs at the end as part of landscape works and involves:

- Earthworks to configure the bathymetry of the wetland
- Installation of the hydraulic control structures including inlet/outlet
- Placement of topsoil, trimming and profiling
- Placement of turf in High Flow Bypass channel to protect against erosion
- Disconnecting the Inlet Zone from the macrophyte zone to allow storm-water to flow along the High Flow Bypass to allow wetland plants to establish
- Planting and water level of macrophyte zone
- Planting at littoral zone and providing irrigation to ensure establishment of vegetation

5.1. Key construction stages

This section describes the overall construction structures for constructed wetlands. Specific details such as finished levels, pond location and planting plan will be included in the design and site construction plans, or as advised by the design engineer during construction. The flow of the construction is shown in Figure 57.

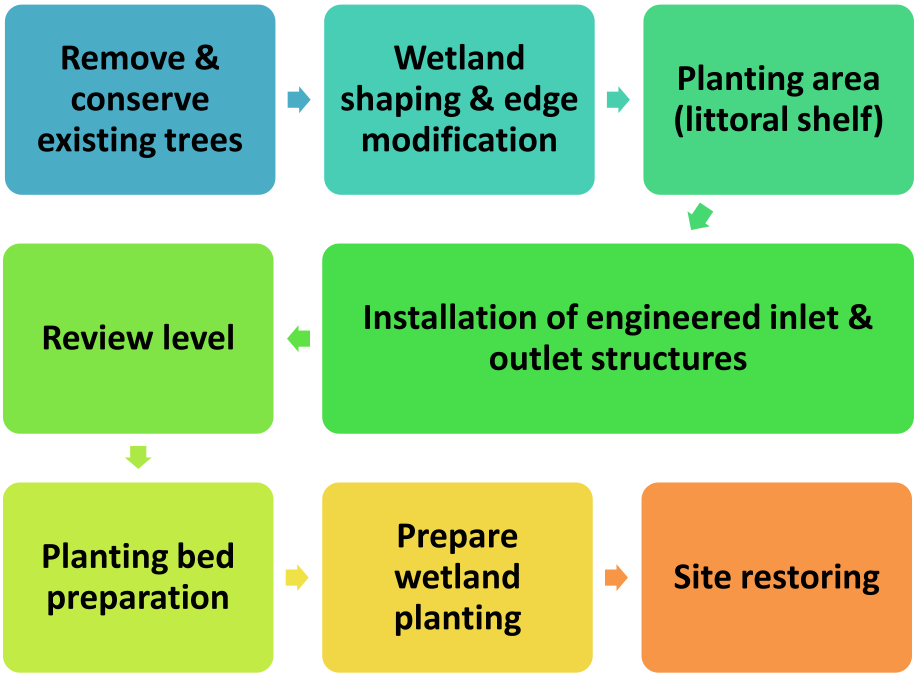


Figure 57: The summarised flow of construction.

5.1.1. Remove and conserve existing trees

Protecting existing trees especially those with high conservation value, should be considered before the excavation. Advice may be sought from arborist or local council for this purpose and protective measures may include fencing off the rootzones of the trees that are to remain for stock piling outside of rootzones. After the necessary protective measures have been taken for the existing trees, excavation of the constructed wetlands can begin.

5.1.2. Wetlands shaping and edge modification

After the necessary protection done for the trees to be conserved, excavation of the constructed wetlands can be started. Excavation should be done according to the shape, levels and in location shown on design plans or as instructed by design engineer (refer to **section 4.2**). It is to note here that the base and edge of the constructed wetlands should be compacted mechanically by using roller or sheep's foot to prevent leaks. Replacement of substrate should be considered if the base substrate is not suitable. The suitability of substrate for constructed wetlands is explained in **section 4.4.10**. The edge of pond and planting zone along with the pond slope should be graded accordingly to the specified level as designed by landscape designer.

5.1.3. Planting area (littoral shelf)

Fine grading of the planting zone should be done at this stage to confirm the position of the planting zone or littoral shelf. The littoral shelf may be formed within the pond area as well as on banks. Therefore, it is recommended to have the planting plan ready at this stage (**section 4.4.5**). Nonetheless, slight modification of the planting area is still allowed at a later stage.

5.1.4. Installation of engineered inlet and outlet structures

The installation of inlet and outlet structures should be done at this stage. The inlet structure (perforated pipe) should be laid perpendicular to the direct flow in the wetland pond which will help to maximise an even flow distribution (**section 4.2.3**). On the other hand, the level of outlet structure must allow the wetland to drain freely to the receiving drainage system (**section 4.1.2**). Liners should be installed at this stage if required (**section 4.4.10**).

5.1.5. Review levels

The finished levels of the constructed wetlands should be reviewed in order to match those levels as specified in the design planning. Incorrect levels may lead to wetland malfunction and reduce the survival of wetland plants.

5.1.6. Planting bed preparation

The soil suitability for wetland plants should be assessed at this stage. Treatment can be done if sand/ clay content too high, where the topsoil or compost can be applied or mixed into existing soil. The root balls of plants should be buried deep in the topsoil or mulch (or secure well with staples and clips). It is further elaborated in **section 5.2.1**.

5.1.7. Prepare wetland planting

Topsoil or compost mix can be applied if necessary, especially along the base of littoral shelf for submerged plants. The ideal topsoil pH value should fall in between 6.5 - 8.5, with humus content greater than 50%. The topsoil should be spread and grade evenly over the area and saturated by watering to a minimum of 100 mm depth. Wetlands plants can then be planted as specified in the planting plan (**section 4.4.5**) prepared by the landscape designer. Weed control and watering schedule should be set up to manage the wetlands plants.

5.1.8. Site restoring

Remove excess materials and equipment from site. Re-instate the area to pre-construction condition. Disassemble sediment and erosion control devices and site health and safety precautions.

5.2. Wetlands vegetation establishment

5.2.1. Seedbed preparation

The easiest way to prepare the seedbed is to saturate the site. This process will aid in the prevention of high spots and vegetation loss. Standing water is much easier to plant as compared to dry soil. All planting is to be carried out manually. The indication that the soil is fully saturated, is when a planter can easily dig a hole using bare hands. It is important to make sure that all the roots are covered with soil before covering it, hence a hole that is deep enough for the roots should be made. The macrophytes zone design guidelines are described in **section 4.4**.

5.2.2. Time of planting

Time of planting is critical for the initial survival of the new wetland and is regionally specific. Planting is not encouraged during monsoon season as the high water level will inhibit plant establishment. It is recommended that planting be carried out during the dry season. However, regular watering is important during the initial phase to ensure that wetland plants will not suffer from heat stress.

5.2.3. Planting depth

Plant materials should be planted deep enough to prevent them from floating out of the planting hole or zone. Water levels can be manipulated to control growth and spread of plants. Flooding may also inhibit the establishment of undesirable species (Figure 52).

5.2.4. Planting spacing

Planting densities vary according to species. Spacing of plants depends on the final size at adult stage. Many wetlands plants will spread 9 – 12 inches (23 – 30 cm) in full growing season. Therefore, wetlands plants such as sedges can be planted at a density of three per square meter. On the other hand, for shrubs that will grow to various heights in between 4 to 10 feet high depending on the species; will need a spacing of 3-4 foot (**section 4.4.7** and Table 13).

5.2.5. Plant establishment and maintaining vegetation

After the wetland cells are planted, the substrate will need to be saturated with water to about 1-inch for four to five weeks. When the submergent plants show new growth, water levels can be slowly and gradually increased to support erect and upright growth forms.

Wetland plants should be allowed to establish before run-offs and wastewater effluents can be discharged into the wetlands. It is essential that stems and leaves of desirable species are above water surface to avoid drowning of new or established plants. However, water levels should never be lowered to expose plant roots as dry cell conditions or lack of water will result in poor survival.

5.2.6. Water level management

Survival of wetland vegetation is depended on fluctuating water levels. Hence, having control structures which are able to regulate water elevations is crucial. Water level management must create similar water depths and duration of flooding throughout the newly planted area (Figure 44 and Figure 58: Healthy condition of wetland vegetation at the edge of the cell A Pond 10.).

The wetland should be fully inundated for a period of 1 -2 weeks prior to planting. This ensures that the wetland sediments are fully saturated which enables the sediments to settle and provide conditions for seedling growth. During the initial stages, the water depth must be controlled. This can be achieved by controlling the outlet valve, isolating inflows from the sediment basins to the macrophyte zone or pumping out the macrophyte zone if required.

Water level controls need to be staged throughout the planting process to ensure that plants in various zones will receive the appropriate amount of water. In addition, periodic water level controls need to be carried out after the macrophytes have been established to prevent the growth of undesired weeds (**Figure 59**).

Figure 58: Healthy condition of wetland vegetation at the edge of the cell A Pond 10.

Figure 59: The succession of grasses at the edge of pond due to poor water level control.

5.3. Measures of successful plant establishment

The wetland vegetation is considered established when plants have reached reproductive maturity and sufficient vegetation cover has been established. Vegetation growth can be recorded through three-monthly photo logs.

The following conditions should be recorded during the plant establishment period:

- Plants are healthy and free from disease
- Minimum vegetation height is 50 cm (except for submerged plants)
- Emergent plants have reached reproductive maturity
- Macrophyte zone have at least 80% vegetation cover

The quality of water will be tested before planting, and after establishment of vegetative growth. The benchmark of the water quality is described in **section 0**. Certain species of common reed could take up nutrients at three weeks of age. Due to variety of plants that will be planted in the wetlands, it is safe to test water quality after three months of establishment. This is to ensure the water filtration system is working correctly.

6.0 The Biodiversity Enhancement

The City of Elmina is a large area of greenery in the middle of an urban environment. Although the area is a well-manicured environment, it does retain the main river flowing through the Central Park Lake system and numerous wetlands ponds within its development areas. With the removal of any natural forest habitats and the clearance of virtually fringing wetland vegetation around the existing lakes, levels of biodiversity are likely to be considerably lower than if natural forest patches remained. However, a wide range of common species of small mammals, birds, amphibian and insect will re-colonise the wetland habitats within City of Elmina if proper habitat structures were created.

Creating habitat structure within the wetland is critical for increasing biodiversity through natural in-migrations. Wetlands with poor habitat structure provide niches for fewer insects and thus fewer birds, amphibians, reptiles, etc. Habitat structure is created through planting a wide variety of wetland plants, fruiting trees, scrubs and creating the variety of water depths that suit each species (or groups of species). For instance, if the shallow wetland zone is all the same gradient it will probably become dominated by a few wetland plant species rather that the desired mix of species. By ensuring that there are deeper depressions or channels and a deep to shallow gradient in the shallow wetland zone (shelf) is one way to add potential structure to the wetland habitat.

Other considerations to add structure are the placement of deadwood and leaf litter areas, construction of over-hangs and shelves to enable amphibians, fish and reptiles to hide from predators. Placement of a large dead tree on the edge of some of the wetland ponds will provide perches for water-birds such as kingfishers and other species such as bee-eaters as well as boring-insect food and will eventually rot and provide organic nutrients to the wetland. For the overhangs under the water surface, this microhabitat can be created through placement of rocks, tree trucks and/or concrete piping partially submerged or hidden beneath lakeside vegetation.

If water management and wetland habitat creation are successful within City of Elmina, there will likely be a wide range of common wetlands and urban bird, amphibian, reptile, mammal and insect species that will naturally colonise the newly created wetland habitats. These colonisations will either be from within the City of Elmina itself or from adjacent urban areas. These species will benefit from the more structured wetland habitats, more food plant species and perhaps breeding sites in the well maintained wetland ponds.

The potential biodiversity and species to be attracted to the wetlands within City of Elmina are described in the following subsection.

6.1. Small mammals

There are several species of mammals that are found in wetlands. These mammals adapted to the wet conditions for food and shelter. They rely on grasses, reeds, seeds, insects, fishes and frogs for food. Among these mammals are tree shrews, rats, squirrels and otters. Otter is an important indicator of a healthy wetland. Their sensitivity to contaminated water and decreasing fish resources made them a vital existence in a stable ecosystem. They are known to reside in constructed wetland in Taman Tasik Metropolitan Kepong, Kuala Lumpur area in which they can be seen hunting and frolicking. More sightings of the otters were also found in other parts of Kuala Lumpur as the water bodies in the vicinity link back to Klang River. Otters have big home range and can travel far. It might be possible for them to migrate to other restored wetlands such as in Elmina City for shelter and food.

6.2. Avifauna

Wetlands are important habitat for various birds. Freshwater habitat serves as foraging ground and breeding sites for of the water birds. Its ecosystem with diverse characteristics provides abundance of food for them. Water is the major factor that affects aquatic vegetation density and composition thus influenced bird density, diversity and distribution. Due to degradation of many natural wetland habitats, constructed wetlands have become a vital habitat for birds that depends on them for shelter, food and water. Apart from their visible presence, the existence of birds in a wetland may indicate the ecological conditions of the area.

Wetlands provide ample feeding opportunities for many species such as bee-eaters and dollarbirds, birds of prey, sunbirds and others (Table 14). All of these bird groups will be enhanced by better creation, restoration and management of wetlands and associated habitats at City of Elmina. The wetland habitats created, restored and managed at the City of Elmina will not only attract resident breeding species (e.g.: White-breasted Waterhen, Little Heron, Red-wattled Lapwing etc) but will also provide important feeding habitats and staging areas for passerine migrants (e.g.: flycatchers, Brown Shrike, warblers, etc).

There are many variations in enhancing the wetland habitat to attract ample bird species. Overall, the wetlands designer should consider the following principles in enhancing wetland habitat:

- Various plants species diversity (the recommended terrestrial plant species is listed in **Annex 02**
- Structural diversity (small and medium trees with some tall emergent)
- Successional phases (from grasses to herbs, bushes to trees)
- Physical continuation of vegetation (to have connectivity within the wetlands and other water courses)
- Inclusion of water bodies (to ensure water supply and insects which require water in their life cycles)

In addition to the above design principles, the following points should be taken into account if healthy bird populations are to be maintained in the designed wetland:

- Nesting materials must be available (woven straws, cobwebs, leave little, twigs etc.)
- Artificial nest boxes can be provided for some species
- Cutting and pruning should be avoided during the main breeding season (March to June)
- Epiphytes and climbers are useful to most bird species and should be encouraged (increases the complexity of tree surface hence providing more hiding spaces)

Some of the common avifauna which can be found at wetlands habitats is listed below.

Table 14: An example of common species of water birds in wetlands.

Name	Habitat	Photo
Purple heron (Ardea purpurea)	Freshwater swamps with dense vegetation	
Javan Myna (Acridotheres javanicus)	Flooded grassy area	
Little Egret (Egretta garzetta)	Rivers, ponds, flood plains, rice fields and swamps	
Striated heron (*Butorides striata*)	Rivers, lakes and streams with dense vegetation and mangrove-lined shores	

Red-wattled Lapwing (*Vanellus indicus*)	Wetlands, marshes, rivers, grass fields and cultivated land	

Box 9: Painted Storks return!

Painted Stork (*Mycteria leucocephala*) is a large and fabulously colorful stork with a striking wing pattern. It has black flight feathers with white barring on mainly black coverts; pinkish tinge on greater coverts and black barring across breast. This species was extinct in wild in Malaysia since mid of 1980s, but fortunately small captive breeding populations in Zoo Negara was developed during that time and were allowed to free-fly from the zoo's breeding colony to other places (to feed in ponds and river bank along Damansara River) within the Klang Valley. Most of the birds will return to the zoo at night to roost in the colony there. Yet, the Painted Storks began to roost outside the zoo (on condominium blocks and light posts along the Federal Highway) in the early of 1990s. Later in late 1990s, the species began breeding at Putrajaya Taman Wetland and other sites in the Klang Valley. The species is now breeding successfully at several sites around Kuala Lumpur and Selangor. There is a high chance that if correct conditions created within City of Elmina, this iconic bird species can be attracted to breed and forage with the wetlands within City of Elmina in future. Painted Stork particularly like shallow water wetlands (10 – 15 cm depth), with little disturbance (for feeding) and small islands within the wetlands with groves of trees for breeding.

6.3. Amphibians

Freshwater ecosystems, including constructed wetlands are home to a wide array of animals including amphibians such as frogs and toads. Wetlands play an important role in the life cycle of frogs because they live in two environments – both land and freshwater. Frogs will be found at a given wetland ecosystem at different phases of their life cycle. Wetland vegetation provides shelter for adult frogs to hide from predators. While vegetation provides shelter for adult frogs, it also serves as a platform for biofilms and organic matter to grow, which are important food sources for tadpoles.

Amphibians such as frogs and toads are good bio-indicators of a wetland ecosystem. As an adult, a frog will breathe through its skin, which absorbs toxic chemicals, radiation and diseases. An indicator of a healthy ecosystem is when there is abundance and diverse of frogs. Table 15 shows examples of some common frog species found in Malaysian wetlands. Most of the species below will naturally colonize urban wetlands once they have been created.

Table 15: Example of common frog species found in wetlands.

Name	**Habitat**	**Photo**
Brown bullfrog (Kaloula baleata)	Prefer disturbed habitats, flood plains of rivers, ponds, ditches	
Banded bullfrog (Kaloula pulchra)	Human settlements, ditches, lawns	
Grass frog (Fejervarya limnocharis)	Disturbed habitats, agriculture fields, rain pools at roadside, lawns, football pitches	

Blyth's wart frog (Limnonectes blythii)	Primary and disturbed forests, along banks of medium-sized streams – turbid/ clear	
White-lipped frog (Chalcorana chalconota)	Near forest edge, shrubs, gardens	
Common green frog (Hylarana erythraea)	Ditches, ponds, agriculture fields	
Cricket frog (Amnirana nicobariensis)	Ponds, rain pools at roadside	
Four-lined tree frog (Polypedates leucomystax)	Human settlements, shrubs, gardens	

6.4. Fish

While plants make a major contribution to the appearance of a wetland, fish bring life to it. They play a role in its maintenance by feeding on aquatic insect and depositing detritus which will benefit the plants.

There are many local species of fish suitable for stocking. The following broad selection criteria are recommended for stocking of fish into the ponds/ wetlands within the City of Elmina:

- Malaysian (native) species only should be considered
- Pelagic (mid-water and surface swimming fish) species provide excellent sports fishing and ornamental attractiveness
- Bottom swimming/feeding species should in general be avoided. Although several species are excellent for sports fishing
- Carnivorous species are usually excellent sports fish and assist in the control of small (zooplankton-eating) species and un-desirable species
- Species with low reproductive potential

The suggested fish species are enclosed in the **Annex 04** .

Timing for introducing fish is important. It is advisable to add fish to the pond at least one month after planting of the last plants. Plants will require time to establish and adding fish to the mix will affect this as the fish may disturb the freshly planted plants while digging in the substrate to search for food. Once the plants are disturbed, it is difficult to re-establish them without emptying the pond and replanting the baskets.

The important point to consider when introducing fish is the difference in temperature between the water in the pond and that in the bag. Usually, the water in the pond will be cooler thus tipping the fish from warm to cold water can stress them and leave them susceptible to diseases. Therefore, it is advised to float the bag on the surface of the pond for about 20 minutes before releasing the fish. Where possible, float the bag in a shaded area of the pond as the sun shining on the bag can make the temperature inside soar.

However, not all fishes are desirable. All urban wetlands in Malaysia have been invaded by Mozambique Tilapia and these alien, invasive species can cause significant management issues due to burrowing and under-cutting of banks.

6.5. Odonata

Odonata are conspicuous insects with two large compound eyes, two pairs of delicate and membranous wings, and a long slender abdomen. Their life history occurs in two different stages: aquatic and aerial stages. The larval stage is spent in aquatic environment, and the adulthood is in terrestrial.

Odonata encompasses of two suborders namely Anisoptera (dragonflies) and Zygoptera (damselflies) consisting of over 5000 species globally. In Malaysia, over 400 species of Odonata from 17 families have been recorded with 180 species of dragonflies and 210 species of damselflies. Odonata are widespread, relatively easy to observe and identify, and they are well dependent on the ecological conditions of the environment. These insects lay their eggs in or near only fresh water and thus, their high abundance in an area is a good indication of the quality of freshwater.

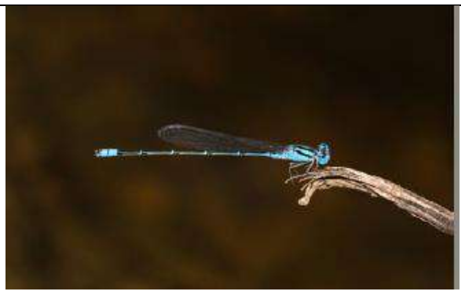
Dragonflies and damselflies are especially important components of urban wetland ecosystems because they predate both mosquito larvae (when they are themselves aquatic larvae) and adult mosquitoes. Dragonflies are key aerial insect predators in the ecosystem.

Odonata species are sensitive to conditions at the breeding site and surrounding terrestrial area. Hence, they have been used as bio-indicators since they provide reliable and qualitative characteristics of an ecosystem's conditions.

Using Odonata as bioindicators have two obvious advantages over chemical tests:

i. It includes reference to a time period (the larvae living in the pond for at least several weeks) rather than a single chemical sample at one particular point in time that may or may not be representative of conditions over the longer period.
ii. It is inexpensive and can be done at most times of year using either mature larvae or adults, or both depending on the time. Table 16 shows some example of common odonata species found in Malaysian wetlands.

Table 16: Example of common dragonfly and damselfly species found in wetlands.

Name	Habitat	Photo
Ceriarigon cerinorubellum	Common in ponds and drains in disturbed open areas	
Pseudagrion microcephalum	Common on lakes, drains and lily pads	
Ischnura senegalensis	Very common in disturbed, open habitats including still and slow flowing water	

Crocothemis servilia	Common in disturbed open habitats	
Neurothemis fluctuans	Very common around lakes and drains	
Brachythermis contaminata	Common around margins of ponds, lakes, drains. Tolerates polluted water.	

Photos courtesy of Dr. Choong Chee Yen

7.0 Management of Healthy Constructed Wetlands

In a constructed wetland, operation, maintenance and monitoring are three important components which forming the integral management of healthy constructed wetlands. It is essential in new wetland management to maintain control and monitor system inflows, outflows, and water level. The elements stated in this manual should be strictly followed to:

- Ensure the wetland design objectives are achieved
- Extend the active life of the wetland
- Facilitate management staff in making decisions and
- Assist operator and maintenance staff to carry out their duties effectively

Assuring the integrity of structural components such as dikes, berms, spillways and water control structures should be a regularly scheduled activity. Each of these structural components should be inspected at least weekly and immediately after an unusual storm event. Damage, erosion or blockage will need to be handled as quickly as possible to prevent further damage to both the structure and the wetlands and to reduce the repair costs.

The constructed wetland is a dynamic system and problems may arise if,

- Managers and operators do not understand the operational and maintenance requirements and procedures;
- The wetlands are overloaded, either hydraulically or by pollution;
- Unavoidable disasters occur, such as serious floods and droughts;
- Serious weed invasion develops and
- Physical and chemical pollutants accumulate and clog up the system.

7.1. Operation

7.1.1. Start-up operation

During the start-up period, the operator is primarily responsible for adjusting the water level in the wetland. In general, the constructed wetlands will have to be saturated with water to the surface of the substrate at the end of planting. As the macrophytes begin to root, the water level can be gradually lowered to the design operating level.

On average, the effective operating depth for a constructed wetlands cell ranged from 0.1 – 1.5 m (**Section 4.1.1**). Proper water depth and careful regulation is a critical factor for plant survival during the establishment phase (normally the first 3 – 6 months). Apart from that, shallow flooding (2 – 5 cm) can limit succession of undesired weed or terrestrial plant species. Therefore, once the planted macrophytes have stems higher than 8 – 12 cm, shallow flooding should be carried out by control the water level to prevent weeding. However, it is absolutely essential to ensure that the stems and leaves of desirable macrophytes project well above the water's surface to avoid drowning the new plants.

Gravity flow is often preferred over mechanical devices. However, the aid of small submersible pumps or portable pumps may be economical and may provide a precise method of water and flow control.

7.1.2. Routine operation

A well designed constructed wetland mostly requires little operator intervention. In routine operation, there are several critical items in which an operator or a manager should particularly pay attention to:

a) Water levels

Water level control is the main operational variable that has a significant impact on constructed wetlands to ensure its values; either the functional value or aesthetic value. Changes in water levels affect the hydraulic residence time, atmospheric oxygen diffusion into water phase and plant cover. Significant changes in water levels should be investigated immediately as they may be due to leaks, clogged outlets, storm water drainage or any other causes. The recommended water level for a healthy constructed wetland is elaborated at **section 4.1** and **section 7.1.1**.

b) Flow uniformity (inlet and outlet structures)

Maintaining uniform flow across the wetland through inlet and outlet adjustments is extremely vital to achieve the expected treatment performance. The inlet and outlet manifolds should be inspected on a routine basis and regularly adjusted and cleaned of debris that may clog the inlet and outlets. Debris removal and removal of bacterial slimes from weir and screen surfaces will be necessary. Submerged inlet and outlet manifolds should be flushed periodically. The aid of high-pressure water spray or mechanical means are suggested to carry out this cleaning.

The influent suspended solids will accumulate near the inlets of constructed wetland over time. Therefore, removal of these solids' accumulation is required.

c) Vegetation

In mother nature, plants communities are self-maintaining and self-sustaining where they will grow, die and regrow again in a complete cycle. Macrophytes species exhibit the same traits in constructed wetlands system as well. Therefore, the primary objective in vegetation management is to maintain the desired plant communities within the wetland by preventing the succession of undesired plant species.

This objective can be achieved via the changes in the water levels and harvesting undesired plants (e.g.: weeds, grasses etc) when and where necessary. Where plant cover is insufficient, management activities to improve the cover may include water level control, reduced loadings and replanting. It is not usually recommended that an action be taken to prevent natural succession of wetland plants. Nevertheless, harvesting of matured macrophytes and litter removal may be necessary depending on the design of a constructed wetlands. Table 17 shows desirable planted species in the 'Enhanced Wetland'.

Table 17: Desirable and planted species in the 'Enhance and Existing Wetlands'.

No.	Scientific Name	Common Name	Vernacular Name
1.	*Phragmites karka* 	Common Reed	Rumput Gedabong
2.	*Lepironia articulate* 	Tube Sedge	Purun
3.	*Typha angustifolia* 	Cattail	Banat
4.	*Scirpus grossus* 	Greater Club Rush	Rumput Menderong
5.	*Eleocharis dulcis*	Spike Rush	Ubi Puron

No.	Scientific Name	Common Name	Vernacular Name
			
6.	*Scirpus mucronatus* 	Bog bulrush	Rumput Kercut
7.	*Scleria sumatrana* 	Sumatran Scleria	Rumput Sendayan
8.	*Rhynchospora corymbosa*	Golden Beak Sedge	Rumput Sendayan

No.	Scientific Name	Common Name	Vernacular Name
			
9.	*Polygonum barbatum* 	Knot Grass	Tebuk seludang
10.	*Ludwigia octovalvis* 	Hairy Malayan Willow Herb	Naleh
11.	*Hanguana malayana* 	Common Hanguana	Bakong

No.	Scientific Name	Common Name	Vernacular Name
12.	*Monochoria hastata* 	Hastate-leafed pond weed	Keladi agas

d) Odour

Odorous compounds are typically associated with anaerobic conditions, which can be created by excessive Biochemical Oxygen Demand (BOD), ammonia and phosphorus loadings. Often, the odour occurs if water is flooded in the surface of the bed therefore uniform distribution of water onto the bed will prevent from odour. If primary treatment size is too large then wastewater may undergo anaerobic condition which may create odour when such water is fed into the constructed wetlands. Nevertheless, such odour is insignificant since wastewater percolates into the wetlands bed quickly if there is no clogging.

7.2. Maintenance

Wetland maintenance need to be carried out regularly to sustain a dense stand of desirable vegetation by removing invading weeds, sediment and litter from the wetlands, to ensure designed objectives is achieved.

There should be a maintenance team, to be led by manager who can supervise the workers on monthly basis. An adequate trained labour force of at least 2 workers must be available for routine work and they must be on site for at least 1 week per month during the maintenance period. Additional grass cutting operators will be needed to ensure adequate cutting and cleaning.

The manager shall inspect the site once a month and shall prepare a record sheet on update condition of all maintenance tasks. The wetland manager is required to conduct the following maintenance tasks:

- For keeping all soft landscape areas in a weed-free and tidy condition and adequately watered.
- Keep the landscaped areas clean and tidy at all times and dispose of all waste materials arising from the cleaning.
- Remove noxious weed.
- Pest control.

Inspections are necessary to be carried out immediately after storms or any other polluting events that may damage the wetlands. A list of wetland maintenance checklist is shown in Table 18. Adequate maintenance access is to be provided to facilitate maintenance tasks to be carried out.

7.2.1. Maintenance of vegetation

Operation and maintenance of the wetlands should aim to sustain a dense stand of desirable vegetation within the wetland. Therefore, the care for vegetation in operation, maintenance and monitoring are interconnected and inseparable. Operators should expect gradual changes in wetland vegetation, as a result of aggressive species out-competing more passive species. Certain plant species may also be introduced to the wetland from the catchment. It is not usually recommended that an action be taken to prevent natural succession of wetland plants.

Table 18: Wetland maintenance checklist.

No.	Inspection details	Actions to be undertaken
A	**Wetland maintenance**	
1.	Check on plant death and replacement if required and removal of dried plant parts and plants with diseases or infected plants	- Replace dead plant if area > 3 m^2 - Pruning of dried plant parts - Remove plant that with diseases or infected if area > 3m^2
2.	Check for presence of weed species especially *Mikania* spp. and other species as shown in (Table 19).	- Check for presence of floating, submerged, exotic and noxious species. - Remove all submerged and floating vegetation that invaded open water area. - Remove weed if invasion area > 1 m^2
3.	Animal pest	Remove Golden Apple Snail manually if recorded.
4.	Insect attack	- Pest like aphids can be disposed off by washing off the plants with a jet of water from a hose; they will fall into the water and be eaten by the fish. - The use of pesticide should be avoided if the presence of caterpillar is not serious, (Warning: Avoid spraying with insecticide.)
5.	Herbivorous fish species	Prevent entry of herbivorous fish species by: i) Putting up signature to prevent residents from releasing herbivorous fishes in the lake. ii) Controlling water inlet.
6.	Algae control	Presence of algae indicates high nutrient level, control inflow of high nutrient water into the water body The method of removing algae is to remove the weeds by hand.
B	General maintenance	
7.	Litter removal	Manually remove debris, litter and rubbish washed from inlet drains to the pond and wetlands. Dispose all collected rubbish off site.

7.2.2. Weed control and maintenance

Weed invasion can dramatically reduce the ability of wetlands to meet its design objectives. For example, Water Hyacinth (*Eichhornia crassipes*) growing in a dense mat will create water quality problems by reducing oxygenation and sunlight penetration. *Mimosa pygra* may reduce diversity and scenic amenity by displacing less vigorous species.

The open water areas are susceptible to invasion by floating and submerged plant species. Floating water plants such as Mosquito Ferns - Azolla and Duckweeds - Lemna can form dense mats, excluding light and reducing dissolved oxygen in the water column and increasing the movement of nutrients through the system. These floating species should be removed as soon as they become apparent. Excessive growth of submerged water plants may lead to water quality problem, odours and impact scenic amenity such as *Hydrilla verticillata*. Table 19 below shows a list of noxious plants or weed species that will need to be removed from wetlands if encountered.

Table 19: Weed species to be continuously eliminated from wetlands.

Species (Family)	Notes
Invasive	Invasive species is an organism – in this case, plant species which causes ecological harm in a new environment where it is not native. It is capable of causing extinctions of native species, competing with native for limited resources and altering habitat.
1. *Ipomoea aquatica* (Convolvulaceae) 	Water Convolvulus/Water Morning Glory/Kangkung. 
2. *Eichhornia crassipes* (Pontederiaceae)	Water Hyacinth/ Keladi Bunting. Well-known floating, invasive weed, that has become a pest in Southeast Asia since the late 1800s.

Species (Family)	Notes
	
3. *Utricularia aurea* (Lentibulariaceae) 	Bladderwort/Lumut Air. Submerged aquatic plant. Local invasive species.
Noxious	Noxious species is harmful weed or injurious weed which threatens agricultural crops and local ecosystems. Traditionally, noxious species is as harmful as invasive species.
4. *Cabomba* spp. (Cabombaceae)  	Aquarium plant, originating from North America. Readily escapes into lakes and can block waterways. 

Species (Family)	**Notes**
5. *Pistia stratiotes* (Araceae) 	Water Lettuce/Kiambang. Exotic. Floating, small herb that forms dense mats, creating anoxic conditions in waters.
6. *Hydrilla verticillata* (Hydrocharitacea) 	Florida Elodea /Hydrilla. Noxious submerged aquatic plants that can grow to the water surface and form dense mats.
7. *Salvinia molesta* (Salviniaceae) 	Water Spangler / Kiambang. Noxious floating fern or Kariba Weed. A small herb that forms dense mats, creating anoxic conditions in waters, and has created havoc in many lakes and dams.
8. Mikania spp. (Asteraceae) 	Mile-A-Minute. Rapidly growing (as fast as 8 cm in a day for a young plant) creeping vine which will cover other plant species.

Species (Family)	Notes
Exotic	Exotic species which also known as non-native species is foreign species which has been introduced in a zone out of its natural distribution. The presence of exotic species, by itself, not necessarily represents a problem. However, it is not encouraged to be introduced in the ecosystem as their impact to the introduced environment is understudy.
9. *Limnocharis flava* (Butomaceae) 	Yellow Bur-head/Jinjir. Exotic from South America. Weed of rice fields, cultivated for edible leaves, produces many floating seeds. 
10. *Mimosa pudica* (Mimosoidae) 	Mimosa/Semalu. Exotic, introduced from South America Sensitive plant. Small, thorny wayside plant, with leaves that droop when touched.

Weeds are a minor problem in inundated cells. Weeds are a more significant problem in the non-inundated cells, where lack of water has reduced plant vigour, leading to subsequent insect attacks. Mortality of wetland plants has paved the way for weed infestation. However, the fringe zone or shallow marsh area may be more prone to weed infestation. Prior to planting, the noxious and exotic species that may compete with planted species need to be removed manually.

After planting programme, weeding has to be carried out once wetland plants have become densely established. The weeding programme can be less vigorously applied and limited to particular noxious and/or exotic species. However, the planted bed will need to be checked for invasion of non-desirable plant species on at least a fortnightly basis during plant establishment.

Table 20: Weed control programme.

Schedule	Weeding activities
Prior to planting	Non-desirable vegetation creates competition with seedlings. Therefore, non-desirable vegetation should be removed either manually or spot spraying with a suitable herbicide prior to planting. Manager may select suitable herbicide which has a short residence time, allowing planting to be undertaken within three days of application.
Post planting	The macrophyte bed will need to be checked for invasion of non-desirable plant species on at least a fortnightly basis during plant establishment. Early action can significantly reduce the magnitude of infestations. During plant establishment, the marsh bed is particularly vulnerable to weed invasion.

7.2.3. Plant health

After the plants are established, they should be monitored for their health condition, as well as for pest and disease attacks.

Plant viability is one of the most important aspects of wetland management. Plants provide several mechanisms vital to the improvement of water quality in wetlands. Visible signs of plant distress should be investigated promptly. Senescence of plant species is common among wetland vegetation. This is a natural cycle and leads to plants browning off and possibly the plant appearing to be dead.

In order to check for senescence, look for signs of new shoots and the health status of root systems i.e. plant is well anchored to the substrate. However, as long as there are signs of new shoots and the plants are well anchored to the substrate, the plants will regenerate.

Plant health can suffer from many factors. Generally negative symptoms of plant health include visible signs such as changes in leaf colour, loss of vitality of vegetative growth, a reduction in size and disappearance of plant foliage. Factors that affect plant health include pest attack, disease infection, nutrient deficiency/overload, poor substrate and inadequate water depth.

7.2.4. Maintenance of terrestrial plants

The terrestrial plants that are planted for habitat enhancement need to be carried out along with the other existing plants within the development. Maintenance work should be conducted once in every 2 months after the establishment of vegetation. The recommended wetlands maintenance calendar for City of Elmina is shown in Table 21 while the inspection checklist is shown in Table 22.

Table 21: Recommended wetlands maintenance calendar for City of Elmina.

	Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
	Activities												
1.	Check on plant death and carry out replacement planting if required; remove dried plant parts												
2.	Check for presence of weed species												
3.	Check for animal pest												
4.	Check for insect attack												
5.	Check for herbivorous fish species												
6.	Algae control												
7.	Litter removal												

Table 22: Inspection checklist.

Monthly inspection checklist		File ref:			
		Inspection by:			
		Date:			
	Checklist		Comments (eg area affected, plant species affected etc)	Action taken*	Follow up required
	No work required	Work required			
Plant health/death					
Replacement required (area > $3m^2$)					
Insect/disease attack					
Other pest species					
Others					
Weed control					
Floating weeds present					
Emergent weeds present					
Submerged weeds present					
Others					
Open water					
Vegetation present					
Algae present					
Others					
Structural conditions					
Sediment build up in pond					
Trash and debris					
Condition of inlet weir					
Condition of outlet weir					

7.2.5. Invertebrate (insect) pest control

Insect pests are a common plant disease. There are some common insects which may attack the wetland plants, for instance, Lepidopterous Stem Borers are commonly found on *Scirpus grossus,* while *Ludwigia octovalvis* is vulnerable to attacks by a small, blue beetle and Aphids tend to be found on *Phragmites karka*. The population of aphids may be controlled by natural predators of this pest, i.e. lady bird beetles, if present in the wetlands.

The Golden Apple Snail *Pomacea sp*, an introduced snail species feeds prodigiously on wetland plants. This pest is present in large numbers in the wetland and may cause damage to the plant vegetation. It grows to about 3-4 cm in size and its presence is readily confirmed by its bright pink egg masses which can be seen on plant tissues just above the water level. It is recommended that removal of this pest be given high priority.

Details on these pests are given in Table 23. Other common insect pests include Leaf Eating Caterpillars *Nymphula depunctalis* (case worms, on *Lepironia articulata*), *Cnaphalocrocis medinalis* (leaf roller on *Phragmites karka*). The incidence of insect attacks would be expected to reduce as the wetland system matures and becomes a distinct sustaining ecosystem.

Table 23: Undesirable insect pests and other pests in the wetlands

Scientific Name	Common Name	Plant Host	Damage
Schoenobius incertellus 	Lepidopterous stem borer	*Scirpus grossus,* 	Larvae bores stems Leading to plant die-back and death
Chilotraea sp. 	Lepidopterous stem borer	*Lepironia articulate* 	Larvae bores stems Leading to plant die-back and death

Scientific Name	Common Name	Plant Host	Damage
Nymphula depunctalis 	Case worm	*Phragmites karka,*  *Lepironia articulate* 	Feeds on leaf tissues, leaving white transparent lower epidermis; larvae live in "cases"
Cnaphalocrosis medinalis 	Leaf roller	*Phragmites karka* 	As above but larvae live inside rolled leaf
Aphis sp. 	Aphids	*Phragmites karka* 	Sucks sap of leaves and young shoots, causing leaf-bronzing and die-back
Pomacea canaliculata, Pomacea spp. 	Golden Apple Snail	*Lepironia articulate* 	Highly competitive. Feeds on leaves and stems. High reproduction rate.

Infestation could lead to severe stunting and death of plants. Integrated Pest Management (IPM) should be practised where IPM involves monitoring of pest population and spraying only when the pest population exceeds a certain threshold value. IPM promotes use of biological control methods and minimises pesticide use, as well as avoids use of hazardous chemicals. Operators are advised to use pesticide to combat plant disease and insect attacks as a last resort only. Table 24 shows some examples of disease or pest response thresholds.

Table 24: Example of disease/ pest response thresholds

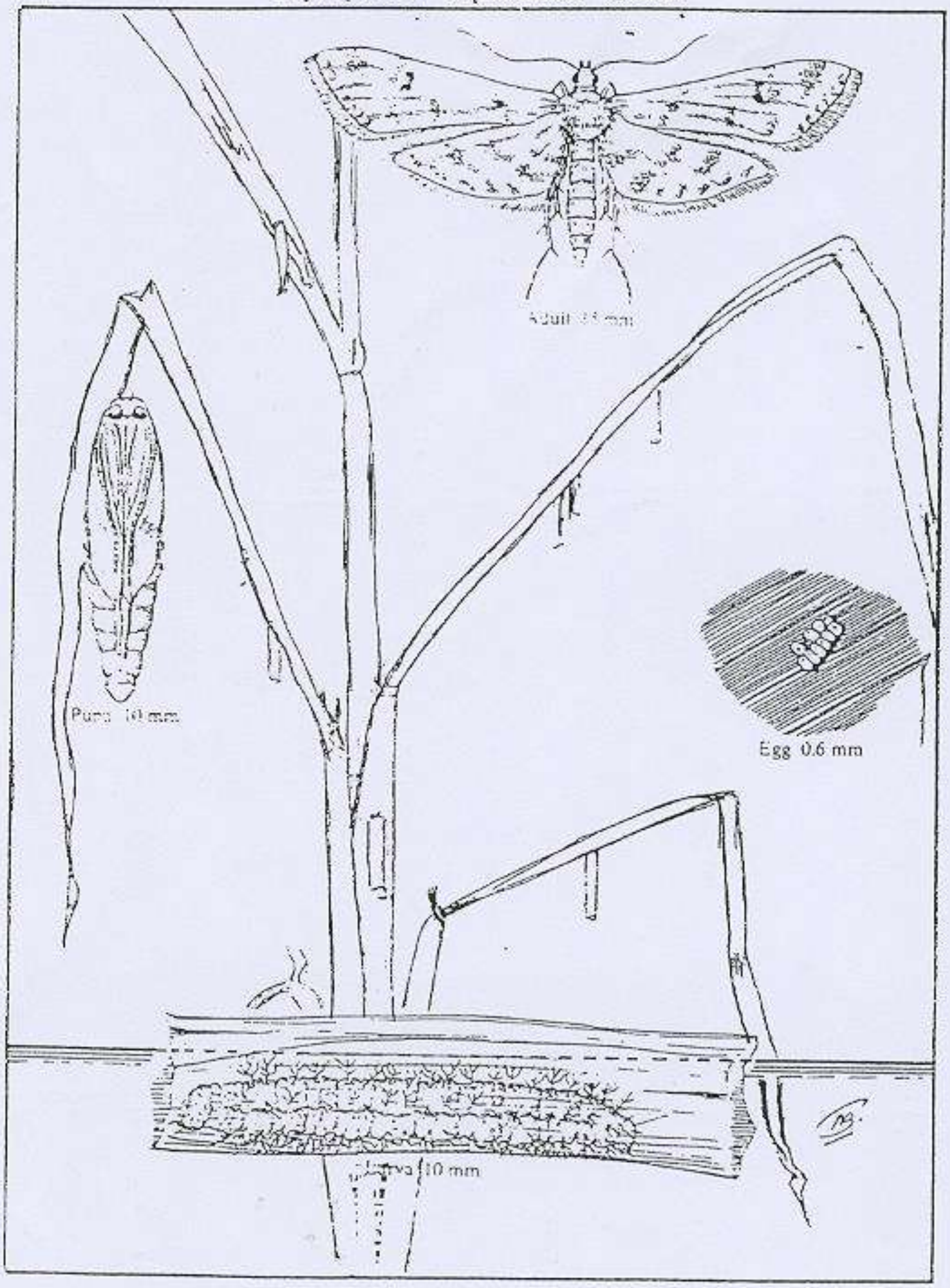
Host organism	Pest/disease	Threshold
Phragmites karka	Aphids	> 25% of a plot infested or > 10 m^2 of reed dead
Phragmites karka	Grasshoppers	> 5 per m^2
Phragmites karka	Leaf cutters	> 10% of a plot infested

Uses of bio-pesticides such as BTs (Bacillus thuringiensis) are recommended. Caterpillar leaf rollers *Cnaphalocrocis medinalis* on *Phragmites* can be controlled using the bio-pesticide *Bacillus thuringiensis* which is harmless for natural predators of the leaf roller and does not affect aquatic life. Rice Stem Borers *Scirpophaga incertulas* on *Scirpus grossus* can be controlled using *Bacillus thuringiensis.*

If biopesticides are not applicable, narrow spectrum, pest specific insecticides are used where effects on non-target organisms is reduced. Aphids on *Phragmites* can be controlled using the systemic insecticide imidacloprid (Confidor), which has little or no effect on non-target organisms such as spiders and aquatic organisms such as fish. Glyphosate should be used as it is non-persistent and biodegradable.

Aquatic life is particularly vulnerable if pesticides are used in this aquatic system and water quality in general will be affected.

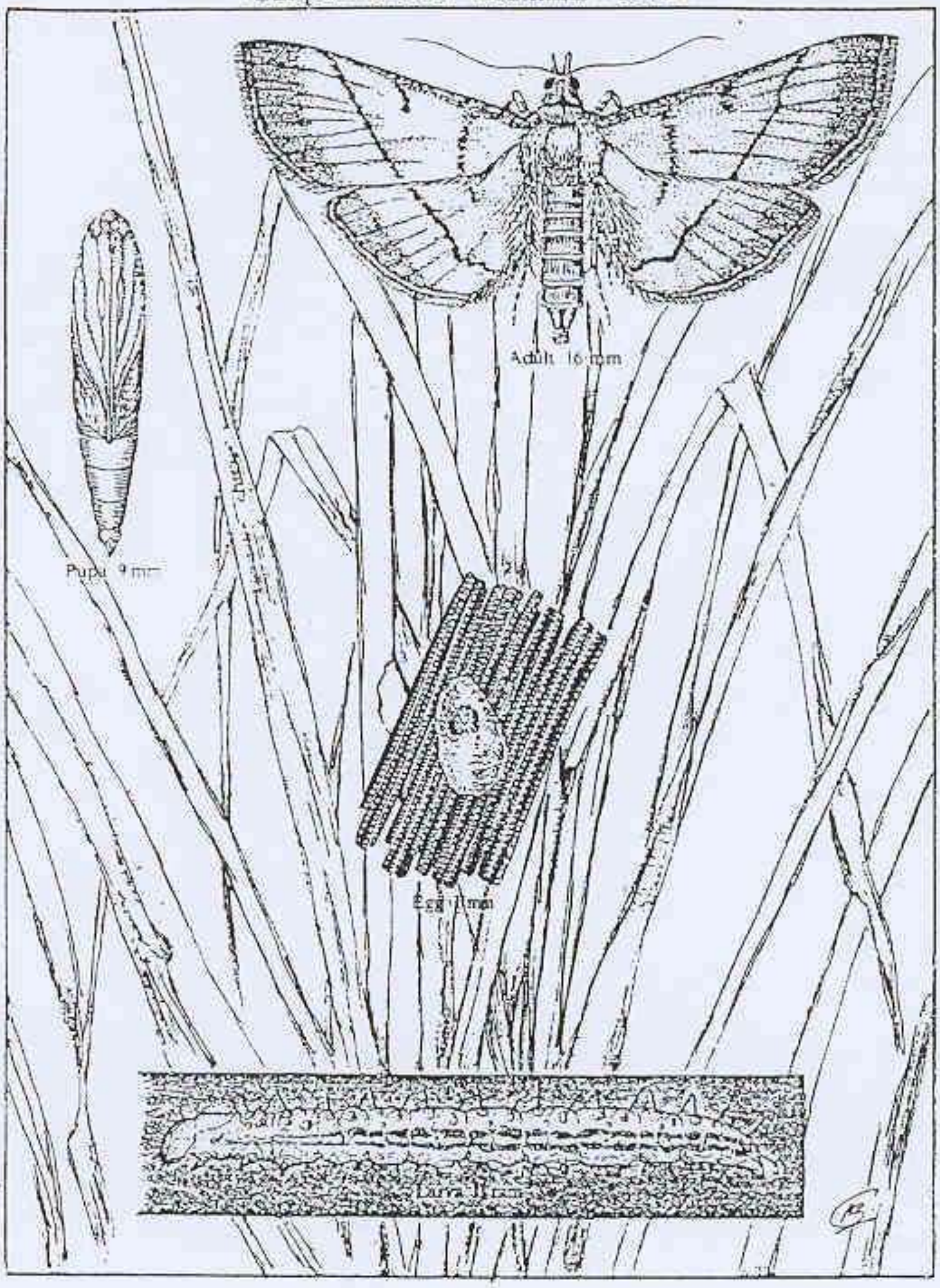
Nymphula depunctalis Guen.



Source . Major Crop Pests in Peninsular Malaysia by Yunus, A. and A. Balasubramaniam (1975) Bulletin No. 138. Min. of Agric. and Rural Develop., Malaysia.

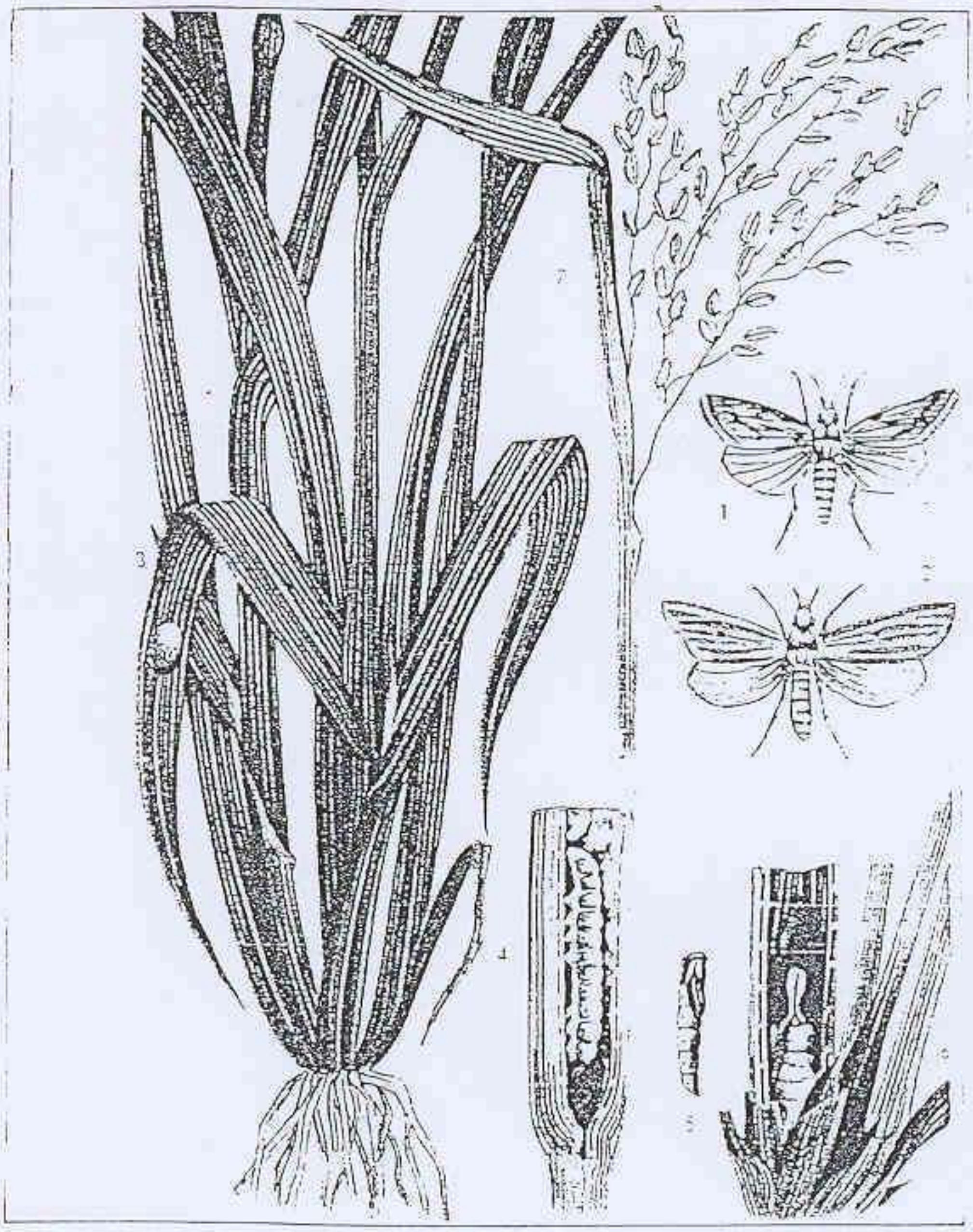
Figure 60: Illustration of insect pest species on wetland plants (Case Worm *Nymphula depunctalis* on *Phragmites karka* and *Lepironia articulate*).

Cnaphalocrosis medinalis Guen.



Source Major Crop Pests in Peninsular Malaysia by Yunus, A. and A. Balasubramaniam (1975) Bulletin No 138, Min. of Agric. and Rural Develop., Malaysia.

Figure 61: Illustration of insect pest species on wetland plants (Leaf roller *Cnaphalocrosis medinalis* on *Phragmites karka*).



Illustrations to show damage by *Schoenobius incertellus* on paddy
(Source : Frolich & Rodewald, 1970).

Figure 62: Illustration of insect pest species on wetland plants (Damage by Lepidopterous Stem Borer *Schoenobius incertellus* on paddy).

7.2.6. Vertebrate (animal) pest control

In many cases, high fish population in the pond is one of the contributing factors to eutrophication and algal blooms, especially in shallow, tropical ponds. Fish are often introduced to urban wetlands to "enhance" the pond life, but in many cases they can lead to reduced pond life and eutrophic states.

Fish in the family Cyprinidae (carps) are typically one of the drivers of eutrophication as they produce several hundred thousand eggs per female per year, and upon hatching these 0+ and 1+ fingerlings are responsible for consuming most or all of the zoo-plankton within a pond. Without a population of zooplankton to consume single celled algae, the algae will bloom. In addition, the mature fish are bottom feeders and continuously stir up the bottom sediments within a pond, re-suspending sediments and nutrients into the water column to prolong the eutrophication process. Exotic fish species in Malaysia, such as Tilapia (*Oreochromis spp.*) from Africa can also contribute to eutrophication in a similar way to carp.

It is therefore important that the species and numbers of fish introduced into such shallow urban wetlands be managed properly. It is recommended that an annual or bi-annual survey of fish populations be undertaken within this and other ponds at City of Elmina to determine the presence and population structure of problem species. Removal of breeding age Cyprinidae, and 0+ and 1+ populations, as well as systematic removal of alien, invasive Tilapia is recommended. Stocking of fish populations with a balance of predatory and non-predatory species, and a reduction of herbivorous species (as they will consume the beneficial filtering plants) is also recommended.

Table 25 shows a list of animal pests in the wetland.

Table 25: Animal species to monitor and control in the wetlands.

Species **Common Name**	**Reason for control**
Oreochromis nilotica (Nile Tilapia) *O. mossambicus* (Common Tilapia) 	Exotic, highly competitive fish species from East Africa. Nile Tilapia are voracious herbivores, while Common Tilapia are omnivores. Highly competitive.
Cyprinus carpio (Common Carp)	Omnivorous, but primarily herbivore and detritivore, bottom feeders, and will churn up mud, and dislodge plants.

Species Common Name	Reason for control
	
Ctenopharyngodon idella (Grass Carp) 	Herbivorous. Feeds on young plant tissues.

7.2.7. Thinning of plant

Research study has proven that thinning of dense above ground biomass will promote growth, thus improve plant uptake. However, thinning programme need to be carefully considered as there are several disadvantages, including:

- Nutrients and sediments are re-suspended during thinning;
- Short-term loss of habitat;
- Disposal of possibly contaminated harvested materials, and
- The cost involved.

7.2.8. Nutrient deficiency

Nutrient deficiency may result in discolouration of vegetation, growth deformities or slow growth rates. Appropriate action needs to be carried out to rectify impending problems, e.g. fertiliser broadcasting or foliar sprays should be conducted as early as possible, before flooding actually takes place.

7.2.9. Sediment removal

Sediment removal (desilting) and plant litter removal in the wetland is important to ensure continued hydraulic conductivity of the substrate. Sediment accumulation levels should be checked on annual basis. However, some sediment may wash down and accumulate in the wetlands over time and should be removed every 1-3 years to avoid the wetlands being silted up.

Sediment removal (desilting) is recommended to be carried out during dry season and to be done in stages (normally when it is half full or around 1 – 2 years) for a pond in order to restore the design capacity. It is recommended to do the desilting in stages to avoid the destruction of all macrophytes at one time. The manager of the constructed wetlands may divide the pond into 2 – 3 zones and do the dredging according to zone.

Sediment should be removed and disposed off-site. Access to sedimentation basin must be maintained to allow machinery to operate on site for sediment removal. In addition, the inlet structure should be checked immediately after every significant rainfall to avoid erosion.

Figure 63: Accumulation of sediment formed small islands after long overdue maintenance

Figure 64: Example of well-maintenance pond with less accumulation of sediment.

Maintenance calendars and inspection checklist can be used to schedule maintenance and operation activities (Table 21 & Table 22).

7.3. Monitoring

Monitoring and inspection programmes are essential to be undertaken to identify problems on site, to collect and document data for operation, maintenance and research purposes at the wetland. An inspection checklist of the wetland monitoring programme is included in Table 26.

Table 26: Wetlands monitoring checklist.

No.	Inspection details	Actions to be undertaken	Action by
1.	Water quality (**Section 0**)	Monitor a full set of water quality on a yearly basis; identify cause if water quality is poor and take appropriate action; to check on eutrophication symptom;	To be contract out
2.	Plant growth and health (**Section 7.3.2**)	To check on plant senescence symptom, nutrient deficiency symptom, vegetative growth, leaf colour.	Maintenance staff
3.	Occurrence of wetland organism (**Section 7.3.3**)	To check on some indicators species of wetland health.	To be contract out

7.3.1. Water quality monitoring

Water quality data is considered a good indication of wetland performance in water quality improvement. It is recommended that water quality be monitored during pre-construction, construction and post-construction phases. It is necessary also to assess the water quality of the wetland if the biota and indicator organisms in the wetland showing deterioration.

Water quality assessment parameters (to achieve Class II)

1. *in-situ* parameters
   - Flow and loading rates
   - Colour (150 TCU)
   - Dissolved Oxygen (5-7 mg/l)
   - Conductivity (1000 µS/cm)
   - Redox potential (≥650 mV)
   - Temperature (Normal +2°C)
   - pH (6-9)
   - Turbidity (50 NTU)
   - Salinity (1%)

2. Laboratory analysis
   - Total Suspended Solids (50 mg/l)
   - Total Dissolved Solids (1000 mg/l)
   - Nitrogen - Nitrate-Nitrogen, Nitrite-Nitrogen, Total Nitrogen, Ammoniacal Nitrogen (0.3 mg/l)
   - Phosphorus (0.2 mg/l)

- Soluble Iron (1 mg/l)
- Mercury (0.001 mg/l)
- Lead (0.05 mg/l)
- Zinc (5 mg/l)
- Iron (1 mg/l)
- Cyanide (CN
- Arsenic (0.05 mg/l)
- Phenols (0.1 µg/l)
- Chemical Oxygen Demand (10-25 mg/l)
- Biological Oxygen Demand (1-3 mg/l)
- Faecal Coliform (100 count/ 100 ml)
- Oil and Grease – Mineral (40 µg/l)
- Oil and Grease – emulsified edible (7000 µg/l)
- Pesticides (2 µg/l)

Water quality index

The Water quality index (WQI) is used to assess the trends in water quality performance. The WQI is derived from a composite mix of six water quality parameters.

WQI = 0.22 SI DO + 0.19 SI BOD + 0.16 SI COD + 0.15 SI AN + 0.16 SI SS + 0.12 SI pH
where
SI DO = sub-index, Dissolved Oxygen
SI BOD = sub-index, Biological Oxygen Demand
SI COD = sub-index, Chemical Oxygen Demand
SI AN = sub-index, Ammoniacal Nitrogen
SI SS = sub-index, Suspended Solids
SI pH = sub-index, pH

WQI

Class I (≥ 92.7):	Conservation of natural environment. Water supply I – no treatment necessary. Fishery I – very sensitive aquatic species.
Class II (76.5 – 92.7):	Water supply II – conventional treatment required. Fishery II – sensitive aquatic species. Recreational use with body contact.
Class III (51.9 – 76.5):	Water supply III – extensive treatment required. Fishery III – common, of economic value and tolerant species; livestock drinking
Class IV (31 – 51.9):	irrigation
Class V (<31):	Polluted

pH, Conductivity, Dissolved Oxygen (DO)

These parameters should be measured at weekly intervals at the same time of a day. An occasional daily profile of each parameter would also provide useful information. The consistent or occasional presence of acidic pH readings will potentially cause the release of sediment bound metals into water. Variation in conductivity should be interpreted in relation to pH and the natural cycle of plant growth and decomposition with the associated uptake and release of ions. A fall in DO concentration at the outlet is to be expected but unusually low concentrations may be caused by blockages in the substrate.

Biochemical Oxygen Demand (BOD)

Good BOD removal has been recorded for all designs of constructed wetlands. An increase in BOD concentrations at the outlet may be caused by the decomposition of leaf litter or algae within the wetland. BOD should be measured at a minimum monthly interval.

Total Suspended Solids (TSS)

TSS removal efficiency is normally good in constructed wetlands but a reduced efficiency may result from inadequate maintenance of the sedimentation basin, inlet pipes and outlet structures and the resuspension of surface particles during storm events.

Nitrates and Phosphates

Nutrients are a significant component of domestic and agricultural wastewater. Their monthly measurement in the water and sediment will assist a programme of wetland maintenance. A prolonged increase in phosphate concentrations at the outlet indicates the need for a phosphate filter of crushed brick, seashells (e.g. oyster) or limestone to be added.

Heavy Metals

If metal contamination is suspected, the measurement of dissolved and particulate water and sediment concentrations at or near the inlet and outlet and near the middle of the wetland will give an indication of metal removal performance. The regular removal of silt from the pre-treatment sedimentation basin will reduce the input of metal contaminated particles on the wetland.

7.3.2. Plant growth and health monitoring

A simple indicator of plant growth is the length of the longest leaf of the plant. Visual inspection for evidence of tip curl, the appearance of pale or bleached spots on the leaf and dead tissue should be carried out at weekly intervals. Colour charts may be used to assess changes in leaf colouration.

Growth of some dominant plant species (increment of shoot length) should be monitored to show normal growth trends from initial establishment to maturity stage.

Percentage of plant survival will be estimated for individual species during plant establishment using a 1 m^2 grid thrown randomly. Where pockets of poor survival rates are noted these will be assessed separately and reasons for its poor performance determined, followed by replanting of the affected areas.

Three plants of each species should be selected randomly for weekly inspection. The following assessment should be carried out.

Visual health

- Presence of deficiency symptoms
- Disease symptoms
- Pest incidence/nature of damage
- Planting success

The spread of planted species within the wetland should be evaluated to indicate the percentage of success in species establishment. Dead plants should be replaced, however the cause of the problem needs to be identified and overcome.

7.3.3. Wetland organism

A checklist of wetland fauna existing in the wetland will provide useful information on plant health and pollution indication. If pollution becomes overloaded in the wetland and the health of the biota or indicator organisms can begin to deteriorate and some may die. Macro-invertebrate sampling is useful and relatively cost-effective, provides a good information base on the health of the wetland.

Macro-invertebrates are sensitive to changes in water quality and quantity and the physical conditions within the wetland. Some examples of biological indicators are included in Figure 65, Figure 66 and Figure 67 as below. If the biota and indicator organisms showing deterioration or the death of some biological indicators been observed, the next step will be to conduct an assessment of the water quality of the wetland as outlined in the next subsection.

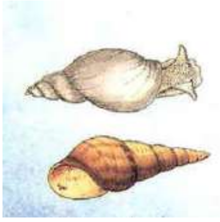
Aquatic Worms (Phylum Annelida) 	**Pouch Snail (Class Gastropoda)** 
Midge Larvae (Family Chironomidae) 	**Leeches (Class Hirudinea)** 
Black Fly Larvae (Family Simuilidae) 	

Figure 65: Pollutant tolerant organism - organisms that are found in poor or polluted water quality water.

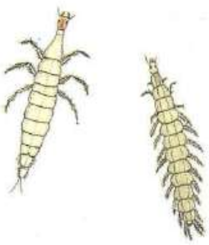
Dragonfly Larvae (Order Odonata) 	Cranefly Larvae 
Beetle Larvae (Order Coleoptera) 	Damselfly (Order Odonata) 

Figure 66: Pollutant intermediate organism.

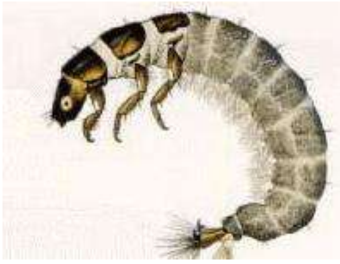
Mayfly Nymphs (Order Ephemeroptera)	Caddisfly Nymphs (Order Trichoptera)
	

Figure 67: Pollutant sensitive organism - organism that are found in good quality water.

7.3.4. Health risk and chemical pollution

The health of the wetland may be affected by the presence and accumulation of toxins from the catchment. Surface runoff may be treated with pesticides e.g. herbicides, fungicides, insecticides or molluscicides and these toxic substances may be accumulated in aquatic organisms and cause bio-accumulation in the food chain. Thus, monitoring of wetland biota is recommended.

Figure 68: The healthy *Sagittaria spp.* found at Pond 10 (left) and the exotic *Limnocharis flava* found at Pond 9 (right).

7.3.5. Wetland monitoring using bio-indicator

Communities of aquatic algae, macrophytes and macro-invertebrates, respond to changes in water quality reflecting both present conditions and past events. Biological monitoring is complementary to chemical monitoring.

7.3.6. Water level management

Currently most of the ponds at City of Elmina are typically function as drainage water retention ponds. Water follows into the ponds from surrounding housing and road areas via drains, and the water is statically maintained within each pond until it exceeds a set depth (around 2 m). Then it flows via an exit sluice into the Sungai Subang. During times of excessive or very heavy rainfall, ponds may fill up, but should never achieve maximum capacity or over flow, if they have been engineered correctly. The volumes of water discharged from the exit sluice during times of heavy rainfall, should exceed the in-flows when the water depth is significantly higher than the 2 m depth established at the over flow. Nevertheless, these types of water retention basin are rarely interesting for biodiversity or aquatic plants.

A well designed constructed wetlands should possess the abilities to absorb and discharge water through their hydrological flows system. These flows are usually characterised by periods of flooding and periods of drought, during corresponding wet and dry seasons or event. These seasonal event result in fluctuation of water levels like natural wetlands, and it is these fluctuations in water levels that often make wetlands significant and attractive for biodiversity, fish and other productivity, flood control, etc.

Reduction in water levels in the wetland may happen during dry season, which may impact the growth and survival of wetland vegetation. Water levels management are important in wetlands with effects on hydrology and hydraulics, and impact on wetland biota.

Figure 69: Absent of wetland plants at the fringe due to low water level at Pond 6

8.0 Towards the Best Practice of Good Design and Management of Constructed Wetlands

Constructed wetland has becoming an increasingly important part of urban housing developments throughout the world, for a variety of reasons. Apart from the aesthetic and recreational qualities outlined in previous section, constructed wetlands provide significant sustainability functions, relating to storm water management, water purification, filtering and waste disposal.

Besides their critical natural functions, constructed wetlands are also increasingly important as recreational and landscape features for urban communities. Wetlands provide green lungs within dense development areas, recreational opportunities such as angling, bird watching and kayaking, to name a few, within the urban setting. In addition, wetlands provide opportunities for environmental education and research through citizen science and school curricula.

The vision of Sime Darby Property (City of Elmina) Sdn Bhd in the development of the City of Elmina has been to “embody wellness and embrace the art of living well”. The development forms an important component of the Selangor Vision City - the township that is the catalyst for growth in the Guthrie Corridor. As such, Sime Darby Property have incorporated extensive green spaces and public spaces into this development.

A total of 27 ponds are planned for the township. The size and layout of these ponds are varied. In addition, the completion stages of these ponds are different. Experts from Wetlands International has visited most of the completed and on-going ponds within CoE (Figure 70).

Figure 70: Location of ponds visited.

From the surveys and observations, the project team concluded that Pond 4 at Elmina East is the most interesting and most natural wetland ecosystem within the CoE development. This pond supported the richest bird and Odonata communities in March 2019, and in June 2020 this legacy was continued. Water quality within this pond was visually extremely good, with clarity to the bottom sediments and high visibility, giving the pond a high aesthetic value (Figure 71). If this water quality and visual aesthetic can be maintained following the completion of the City of Elmina development, this lake has high potential to be the “Jewel in the Crown” of City of Elmina.

Figure 71: Blue and pristine water attracts diverse dragonflies and bird species.

The site is fringed by a shelterbelt of mature to semi-mature *Acacia* woodland and other scrub. This shelterbelt has provided a good buffer between the pond and the Sungai Subang against noise pollution from the adjacent Guthrie Corridor Expressway and Elmina junction. Without this belt of trees, the pond would be exposed to significant noise pollution and disturbance. It is unlikely that it would continue to support a population of Lesser Whistling Duck (*Dendrocygna javanica*), Purple Heron (*Ardea purpurea*) and the otters observed here by SDPB staff. All these species require peaceful and un-disturbed habitats to survive at City of Elmina.

It is exceedingly rare that a lake ecosystem such as Pond 4 can be found in within an urban or peri-urban setting in Malaysia. The visual quality and clarity of the water, the peaceful aesthetic of the site and the wildlife that the site supports all point to the conclusion that this lake should be maintained as close as possible to its current state and feature as a showcase of SDP-CoE efforts to conserve and protect the environment along with its biodiversity for future residents of City of Elmina.

In order to ensure that Pond 4 remains in good condition and provides recreational, aesthetic, biodiversity and other services for the community, it is imperative that the top management within SDP-CoE and City of Elmina agree on the need to protect and conserve this area and eliminate any potential negative impacts of the proposed adjacent development zone.

It is recommended to enhance the vegetated buffer-zone around Pond 4 with native fast-growing pioneer tree species. The suggested approach would be to clear small areas of *Acacia* spp. and supplementary plant the woodland with fast growing, pioneer native tree species such as *Mallotus paniculatus*, *Trema orientalis*, *Macaranga* spp., and *Microcos tomentosa* that can out-compete and shade out *Acacia* seedlings and its young trees (Figure 72).

Figure 72: Suggested native fast growing plants to be planted *Mallotus paniculatus* and *Microcos tomentosa*.

Apart from that, at least 100 m of vegetated buffer zone should be maintained between the proposed sports facility development and the lake edge. In short term, the buffer zone will allow sediment and surface run-off to settle down before reaching the lake thus prevent water pollution to the lake. While in the long-term, the designated buffer zone can be ear-marked for development as a "nature park" or "nature education zone" within the City of Elmina. This can be done by enhancing the micro-habitats (small habitats) such as small ephemeral wetlands with supplementary planting the native species to provide added value for education and recreation as the site currently already housing such microhabitats (Figure 73).

Figure 73: The ephemeral microhabitats sighted at Pond 4 is a good site for community education to identify dragonflies and birds. The site can serve as buffer zone to prevent water pollution of lake as well.

Apart from Pond 4 at Elmina, Pond 10 at Elmina West is another pond that is interesting as the pond has already developed healthy fringe of littoral aquatic vegetation consisting mostly of sedges (*Carex spp.*) and arrowheads (*Sagittaria spp.*) at site. This is a good indication of well controlled water levels at the pond during the establishment phase and mature phase. The water levels management should be continued to prevent the succession of undesired weeds at site. However, it is to note that vegetation management (as described in **section 7.2.1** and **7.2.7**) should be carried out as planned to maintain this healthy vegetation.

Figure 74: The healthy aquatic plants – sedges (*Carex spp*.) and arrowheads (*Sagittaria spp*.) found fringing at Pond 10.

In addition, the site exhibits a good wildlife connection with the adjacent forest – Bukit Cherakah Forest Reserve, hence it has potential to attract different biodiversity, especially the avifauna which using the forest edge, may move into this area once the pond and development mature. Therefore, it is important to enhance the landscape with terrestrial trees which are attractive to avifauna (refer **section 6.2** and **Annex 0** for elaboration). One good example has been adopted at site where the upper pond has a small island developing at its western end, and this is being developed into a larger island in the hope of attracting birds. However, improvement should be made to maintain and manage the tree planted in the middle of the small island as it is not in a healthy condition.

Figure 75: The terrestrial plants around Pond 10 will be able to attract more avifauna to move into the site, once these trees are matured and start producing flowers and fruits.

Annex 01

Checking Tools

This section provides a number of checking aids for designers and management.

Design assessment checklist

This presents the key design features to be reviewed when assessing a design of a wetland. These considerations include configuration, safety, operational and maintenance issues which should be addressed during the design phase.

Constructed wetland design assessment checklist

Wetland location:

Catchment area (ha):

Wetland area (m^2):

Minor flood (m^3/s):

Major flood (m^3/s):

Inlet zone	**Y**	**N**	**Action required**
Discharge pipe/structure to inlet zone sufficient for maximum design flow			
Scour protection provided at inlet for inflow velocities			
Configuration of inlet zone (aspect, depth and flows) allows settling of particles >125 µm			
Bypass weir incorporated into inlet zone			
Bypass weir length sufficient to convey 'above design flow'			
Bypass weir crest at macrophyte zone top of extended detention depth			
Bypass channel has sufficient capacity to convey 'above design flow'			
Bypass channel has sufficient scour protection for design velocities			
Inlet zone connection to macrophyte zone overflow pit and connection pipe sized to convey the design operation flow			
Inlet zone connection to macrophyte zone allows energy dissipation			
Structure from inlet zone to macrophyte zone enables isolation of the macrophyte zone for maintenance			
Inlet zone permanent pool level above macrophyte permanent pool level			
Maintenance access allowed for into base of inlet zone			
Public safety design considerations included in the inlet zone design			
Where required, gross pollutant protection measures provided on inlet structures (both inflows and to macrophyte zone)			
Macrophyte zone	**Y**	**N**	**Action required**
Extended detention depth >0.25m and <0.5m			
Vegetation bands perpendicular to flow path			
Appropriate range of macrophyte vegetation (ephemeral, shallow, marsh, deep marsh)			

Sequencing of vegetation bands provides continuous gradient to open water zone			
Vegetation appropriate to selected band			
Aspect ratio provides hydraulic efficiency = >0.5			
Velocities from inlet zone <0.05 m/s or scouring protection provided			
Public safety design considerations included in macrophyte zone			
Maintenance access provided into areas of the macrophyte zone			
Safety audit of publicly accessible areas undertaken			
Freeboard provided above extended detention depth to define embankments			
Outer structures	**Y**	**N**	**Action required**
Riser outlet provided in macrophyte zone			
Notional detention time of 48-72 hours			
Orifice configuration allows for a linear storage-discharge relationship for full range of the extended detention depth			
Maintenance drain provided			
Discharge pipe has sufficient capacity to convey maximum of either the maintenance drain flows or riser pipe flows with scour protection			
Protection against clogging of orifice provided on outlet structure			

Annex 02

Recommended plant species

Fringing marsh/swamp zone (0 – 0.3m above normal water level)

Botanical name	**Common/Local name**
Alocasia macrorrhiza	Elephant's ear
Alstonia spathulata	Marsh pulai; pulai paya
Commelina nudiflora	Common spiderwort; rumput aur
Crinum asiaticum	Spider lily; Bakong
Cyperus halpan	Sheathed flatsedge; para air
Cyperus digitatus	Finger flatsedge; rumput musang
Cyperus compactus	Swamp mariscus; para-para
Shorea longifolia	Meranti hitam paya
Dillenia suffruiticosa	Simpoh air
Eleocharis variegata	Spike rush; purun
Eugenia longifollia	Common kelat
Eriocaulon longifolium	Asiatic pipewort; Rumput butang
Fimbristylis miliacea	Rumput tahi kerbau
Ludwigia octovalvis	Shrubby water primrose; Lakum air
Pandanus immersus	Pandanus; rasau
Ploiarium alternifolium	Cicada tree; riang riang
Shorea platycarpa	Light red meranti; meranti paya
Polygonum barbatum	Knot grass; Panji-panji
Rhynchospora corymbosa	Golden beak sedge; rumput sendayan
Saraca thaipingiensis	Gapis
Artocarpus altilis	Breadfruit; Sukun
Cyrtostachys lakka	Red-sealing was palm; pinang raja
Melaleuca leucadendron	Paper-bark tree; gelam
Pometia pinnata	Langsir
Sindora coriaceae	Sepetir licin

Swamp forest (0.3 – 1.5m above normal water level)

Botanical name	**Common/Local name**
Alstonia spathulata	Marsh pulai; pulai paya
Artocarpus heterophyllus	Jackfruit; nangka
Caryota mitis	Fish-tail palm; Tukas
Centella asiatica	Indian pennywort; Pegaga
Commeline nudiflora	Common spiderwort; rumput aur
Cerbera odollam	Yellow-eyed cerbera; pong-pong;buta-buta
Cratoxylon arborescens	Geronggong
Dillenia suffructicosa	Simpoh air
Santiria rubiginosa	Kedondong
Elaeocarpus nitidus	Walnut oil fruit; pinang punai
Eugenia aquea	Water apple; jambu ayer

Eugenia longifolia	Kelat
Ficus benjamina	Beringin
Ficus microcarpa	Malayan banyan; jejawi
Flagellaria indica	Rotan dini
Garcinia mangostana	Mangosteen; semetah
Hibiscus tiliaceus	Sea hibiscus; bebaru
Saraca thaipingiensis	Gapis
Ixora javanica	Javanese Ixora
Ixora umbellate	Malayan white Ixora
Lansium domesticum	Langsat
Licuala spinosa	Palas
Litsea teysmanni	Medang kelor
Melaleuca cajuputi	Paper-bark tree; gelam
Nepenthes gracilis	Slender pitcher plant; periuk kera
Pomentia pinnata	langsir
Shorea parvifolia	Meranti bunga

List of recommended plant species for the macrophyte zone

Zone 1: Shallow marsh (0 – 0.3 m)

Botanical name	**Common/Local name**
Eleocharis variegata	Spike rush; Purun
Eriocaulon longifolium	Asiatic pipewort; Rumput butang
Fimbristylis globulosa	Rumput sadang
Fimbristylis miliacea	Rumput tahi kerbau
Hanguana malayana	Common hanguana; Bakong
Ludwigia adscendens	Floating Malayan willow; Water primrose; Inai pasir
Ludwigia octovalvis	Shrubby water primrose; Lakum air
Monochoria hastate	Arrowleaf pondweed; Keladi agas
Phylidrum lanugisonum	Fan grass; Rumput kipas
Polygonum barbatum	Knot grass; Panji-panji
Rhynchospora corymbosa	Golden beak sedge; Rumput sendayan
Saccharum spontaneum	Swamp sugar cane; Tebrau
Scleria sumatrensis	Sumatran scleria; Rumput kumba

Zone 2: Marsh (0.3 – 0.6 m)

Botanical name	**Common/Local name**
Eleocharis dulcis	Spike rush; Ubi puron
Fuirena umbrellata	Hairy blue sedge; Rumput kelulut
Lepironia articulata	Tube sedge; Purun; Kercut
Phyllidrum lanuginosum	Fan grass; Rumput kipas
Scirpus grossus	Greater club rush; Rumput kumbar
Scirpus mucronatus	Upright club rush; Rumput bulat

Scleria sumatrensis	Sumatran scleria; Rumput kumba
Typha angustifolia	Cat-tail; Lembang
Typha latifolia	Bulrush; Banat

Zone 3: Deep marsh (0.6 – 1.0 m)

Botanical name	**Common/Local name**
Cyperus compactus	Swamp mariscus; Para-para
Cyperus digitatus	Finger flatsedge; Rumput musang
Cyperus halpan	Sheathed flatsedge; Para air
Lepironia articulata	Tube sedge; Purun; Kercut
Nelumbo nucifera	Sacred lotus; Seroja India
Nymphae nouchali	Star lotus; Teratai putih hutan
Phragmites karka	Common reed; Rumput gedabong
Scirpus grossus	Greater club rush; Rumput kumbar
Scirpus mucronatus	Upright club rush; Rumput bulat
Typha angustifolia	Cat-tail; Lembang
Typha latifolia	Bulrush; Banat

Source: MSMA 2nd Edition 2012 and Wetlands International, Malaysia

Annex 03

List of recommended terrestrial plant species that are attractive to avifauna

Description	Scientific name	Local name	Type
Plant species that attract insects to their flowers, bear fruits that are attractive to birds and bear flowers that attract nectarivorous birds	*Eugenia grandis*	Jambu laut/ sea apple	Tree
	Fagraea fragrans	Tembusu	Tree
	Vitex pinnata	(Leban/ Malayan teak)	Tree
Plant species that attract insects to their flowers and bear fruits that are attractive to birds	*Eugenia longifora*	Kelat	Tree
	Rhodamnia trinervia	Poyan/ silver back	Tree
	Melastoma malabathricum	Sendudok	Shrub
Plant species that attract insects and nectarivorous birds to their flowers	*Eugenia malaccensis*	Jambu bol/ Malay apple	Tree
	Cocos nuceifera	Kelapa/ coconut	Palm
	Ixora javanica		Shrub
	Lonicera spp.	Honeysuckle	Climbers
	Musa spp.	Pisang/ banana	Herbs
Plant species that attract nectarivorous birds to their flowers and bear fruits that are attractive to birds	*Adinandra dumosa*	Tiup-tiup	Tree
	Sterculia rubiginosa	Rusty sterculia	Tree
Plant species that provide food for frugivorous and insectivorous birds	*Ficus benjamina*		Tree
	Ficus caulocarpa	Ara	Tree
	Ficus heteropleura	Ara	Tree
	Ficus microcarpa	Jejawi	Tree
	Ficus variegata	Ara	Tree
	Ficus virens	Grey fig	Tree
Plant species that attract insects to their flowers	*Ardisia elliptica*		Shrub
	Areca catechu	Pinang	Palm
	Averrhoa carambola	Belimbing/ starfruit	Tree
	Bhesa paniculata	Malayan spindle tree	Tree
	Bulbophyllum macranthum		Epiphytes
	Dendrobium anosmum		Epiphytes
	Dillenis indica	Peradun	Shrub
	Ixora javanica	Ixora	Shrub

Description	Scientific name	Local name	Type
	Malaleuca leucadendron	Paper bark tree	Tree
	Ocimum basilicum	Selaseh	Shrub
	Zoysia matrella		Grass
Plant species that bear fruits and attractive to birds	*Anisophyllea disticha*	Kayu pacat	Tree
	Antidesma ghaesebilla	Guncak	Tree
	Cinnamomum iners	Kayu manis	Tree
	Embelia ribes	Common embelia	Climbers
	Macaranga hypoleuca	Mahang putih	Tree
	Macaranga tanariys	Hairy mahang	Tree
	Medinilla hasselti	Hasselt's medinilla	Epiphytes
	Piper caninum	Sireh utan	Climbers
	Rhodomyrtus tomentosa	Kemunting	Shrub

Annex 04

List of recommended fish species to be introduced in lacustrine habitat

Scientific name	Common name	Local name
Barbonymus schwanefeldii	Tinfoil barb	Ikan lampam
Barbonymus gonionotus	Jawa barb	Lampam Jawa
Cyclocheilichthys apogon	Beardless bard	Chemperas
Esomus malayensis/metallicus	Malayan flying barb	-
Parachela oxygastroides	Glass barb	Ikan lalang
Puntigrus tetrazona	Tiger barb	Pelampong jaring
Rasbora trilineata	Scissortail rasbora	Ikan seluang
Clarias batrachus	Walking catfish	Ikan keli
Aplocheilus panchax	Blue panchax	Kepala timah
Parambassis siamensis	Siamese glassfish	Ikan seriding
Pristolepsis grooti	Malayan leaf-fish	Ikan patong
Anabas testudineus	Climbing perch	Ikan puyu
Helostoma temminckii	Kissing gourami	Ikan tembakang
Betta imbellis	Crescent betta	Ikan belaga
Osphronemus goramy	Giant gourami	Ikan kaloi
Trichopodius trichopterus	3-spot gourami	Ikan sepat
Trichopsis vittata	Croaking gourami	Ikan karim
Osteochilus sp.	Cyprinids	Ikan terbul
Channa striata	Striped snakehead	Ikan aruan

Species to Avoid

These species will need to be avoided at all cost as they are very aggressive and will reduce or destroy the local diversity:

1. Peacock bass (many species) – large cichlids, currently a game fish species in Malaysia
2. African catfish (*Clarias gariepinus*)
3. All Tilapia (cichlid species from Africa & South America)

Annex 05

Attendance presentation on 12th Feb 2020

ITEM	NAME	ORAGNIZATION
1.	Velayutham a/l V Ramasamy @ Ramiah	Sime Darby Property Berhad
2.	Siti Akmar Kamarol Zaman	
3.	Nik Mastura Mohammad	
4.	Mohamed Shukri bin Abdul Aziz	
5.	Badariah Mohamed	
6.	Raja Zalina Raja Azman	
7.	Lela Wani Ismail	Lineworks & Space Sdn Bhd
8.	Mohamad Firdaus bin Sa'ari	Mentari Design
9.	Shireen Shazana Mohd Shaib	Urbanscape Consultant Sdn Bhd
10.	Tan How Hang	Just Right Design Sdn Bhd
11.	Dato' Keizrul Abdullah	Wetland International
12.	Yong Hua Mei	

Attendance presentation on 8th April 2020

ITEM	NAME	ORAGNIZATION
1.	Velayutham a/l V Ramasamy @ Ramiah	Sime Darby Property Berhad
2.	Ahmad Yusri Mat @ Mat Yusoff	
3.	Siti Akmar Kamarol Zaman	
4.	Nik Mastura Mohammad	
5.	Mohamed Shukri bin Abdul Aziz	
6.	Badariah Mohamed	
7.	Raja Zalina Raja Azman	
8.	Lela Wani Ismail	Lineworks & Space Sdn Bhd
9.	Amir Hamzah Abdul Rahim	Mentari Design
10.	Rozita Abdul Hamid	Urbanscape Consultant Sdn Bhd
11.	Shireen Shazana Mohd Shaib	
12.	Farid Haziq	Just Right Design Sdn Bhd
13.	Dato' Keizrul Abdullah	Wetland International
14.	Yong Hua Mei	

Glossary

Constructed Wetlands	Man-made systems or engineered wetlands that are designed, built and operated to emulate functions of natural wetlands for human desires and needs. It is created from a non-wetland ecosystem or a former terrestrial environment, mainly for the purpose of contaminant or pollutant removal from wastewater.
Evapotranspiration	The loss of water from a given area during a specified time by evaporation from the soil surface and by transpiration from plants.
Exotic	Plants or animals introduced into a community that are not native to the area. An alien species.
Monitoring	Collection and analysis of financial and non-financial information on a regular basis in order to check a project's performance compared with its stated objectives, budget and work plan. Monitoring is normally seen as an internal project activity, but can also be external (by outsiders). Monitoring is normally concerned with inputs, activities and outputs. Monitoring systems can, however, also generate information on progress at the purpose level.
Noxious	An animal, plant or disease which is declared harmful by law and which must be eradicated.
Pest	An animal or plant that is directly or indirectly detrimental to human interests, causing harm or reducing the quality and value of a harvestable crop or other resource. Weeds, termites, rats, and mildew are examples of pests.
Senescence	The process of plant degeneration that generally occurs at the end of the growing season. It is typically characterized by increasing respiration, decreasing growth rates, chlorophyll breakdown, and mobilization of nitrogen out of leaves and into other plant organs.
Succession	The natural and gradual replacement of one plant community by another.
Sustainable	Of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged, OR Relating to a human activity that can be sustained over the long term, without adversely affecting the environmental conditions
Terrestrial landscape	The land cover types such as grasses, shrubs, trees, bare ground and shallow water (where the shrub or tree-line is advancing).
Weeds	A plant that interferes with the management objectives at a particular location. It is a plant growing where it is not wanted. Under certain situations, the plant may not be totally undesirable.

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Part 03: Observation Report of Rapid Assessment

At Ponds and Water bodies in City of Elmina

Observation Report of Rapid Assessment

At Ponds and Water bodies in City of Elmina

For:

Prepared by:

Submitted on:
17th July 2020

Project Background

The City of Elmina (CoE) is an initiative by Sime Darby Property (City of Elmina) Sdn Bhd (SDP-CoE) which covers an area of 5,000 acres of land and water bodies. The said project is being developed for residential, commercial, industrial, public amenities, infrastructure/utilities, open space and detention pond areas.

Wetlands International Malaysia (WI) has been commissioned by SDP-CoE to provide consultancy input and advisory services towards the development of lakes and ponds within City of Elmina development in Shah Alam. In March 2019, the technical team of WI along with the associate experts have surveyed and obtained a baseline on the biodiversity present and other information on the general environmental conditions (e.g.: topography, hydrology flow - particularly those associated with the wetlands) at the site. An interim report was finalised by July 2019, with specific recommendations for management of the wetlands, and the biodiversity they support both during future construction activities and following completion of the development.

In early 2020, further assistance from WI was requested to provide recommendations for sustainable wetland management of the ponds and the connecting riverine corridor. In particular, there seemed to be a realisation that some of the ponds within City of Elmina are rich in biodiversity and have the potential to form a central feature within the completed property development. Several staff and contractors from SDP-CoE have reported numerous wildlife sighting from around the site, including otters (probably Smooth Otter *Lutrogale perspicillata*), and it was felt important that these should be considered in the final management and operations for the ponds and river reserve.

The survey team was led by Ms. Yong Huai Mei (Senior Technical Officer at WI), Mr John Howes (Wetland Specialist and Associate Expert for WI), Nadirah Manaf (Technical Officer at WI) and Shahrul Shahpuan (Trainee Technical Officer at WI). Due to the COVID-19 global pandemic and the Movement Control Order imposed in March 2020, this follow up survey were not possible until June 2020.

This report details the results of the rapid assessment by Wetlands International Malaysia of six ponds and the Sungai Subang floodplain area at the City of Elmina development on 17th June 2020.

Methodology

The rapid assessment surveys took place from 9am until 5pm on 17th June 2020. Each pond (site) within the City of Elmina development was visited on foot and at least 1 hour spent at each site. During that time, the WIM team completed the following tasks:

a) On-site discussions with representatives of SDPB regarding issues or potential issues relating to the maintenance and management of each wetland and pond during the development process;
b) Rapid assessment of any biodiversity present and an overview of current environmental conditions, particularly water levels and potential for water level optimisation; and,
c) Develop an understanding of the hydrological flows through the development and how these will impact future management scenarios.

Biodiversity surveys were undertaken using Swarowski 10x42 binoculars and a Kowa 30-60x field telescope mounted on a tripod. Birds were identified using Jeyerajasingam and Pearson (1999) – A Field Guide to the Birds of West Malaysia and Singapore; and Odonata were identified using Orr (2005) – A Pocket Guide to the Dragonflies of Peninsular Malaysia and Singapore. Additional identifications were made using the iNaturalist App – a global citizen science app developed by the California Academy of Sciences in 2008. A Kowa smartphone adapter and Samsung Galaxy A8+ smartphone camera was used to photographically record any interesting biodiversity (where possible) and/or record species for identification.

A map of the City of Elmina, showing each pond surveyed, is provided below (Figure 76). The following section of this report details the results of the surveys at each of the six ponds visited.

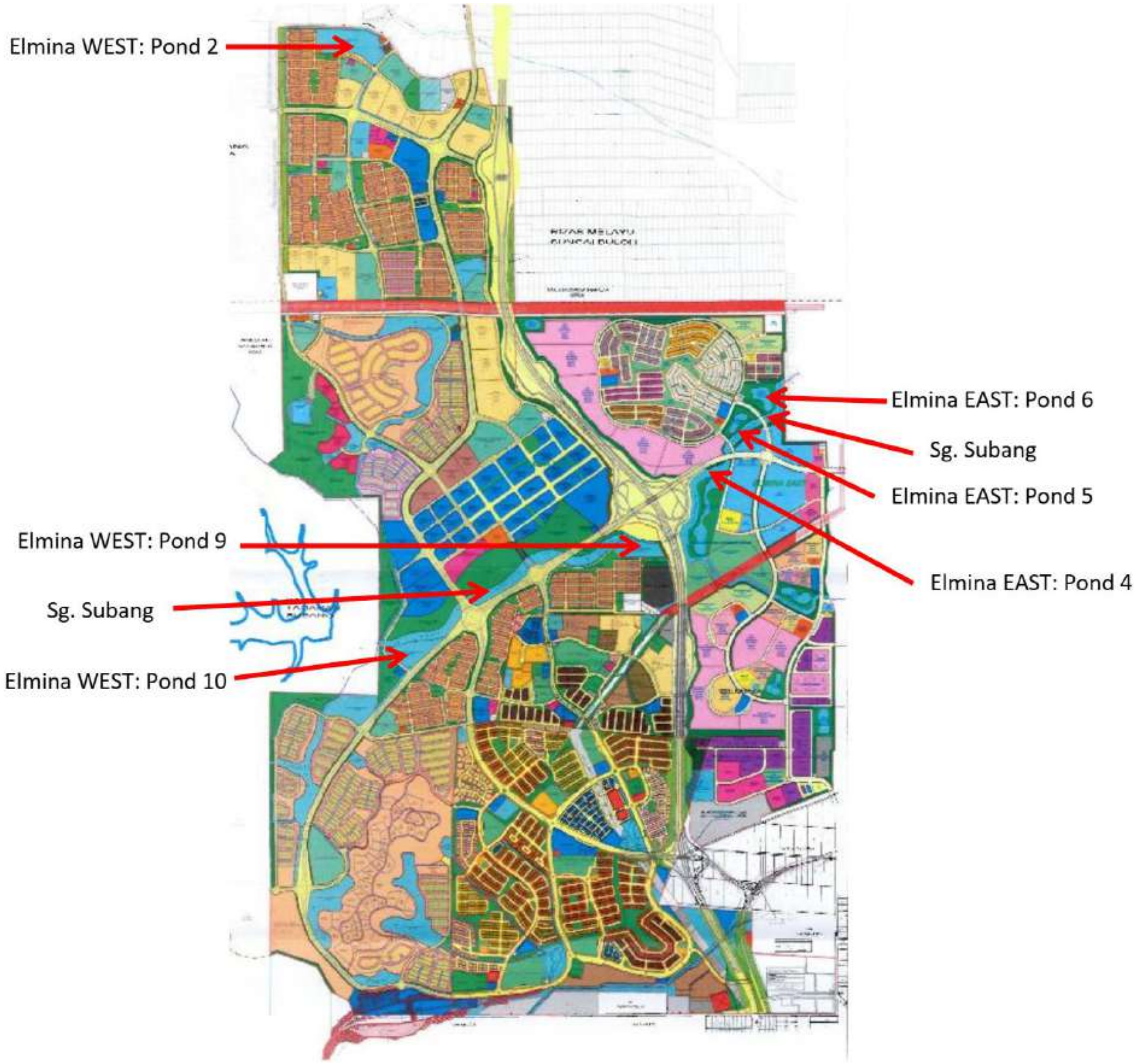

Figure 76: The locations of ponds and water bodies surveyed.

Result of Observations and Discussion

Wetlands in Elmina East

Pond 4

Elmina East Pond 4 continues to be the most interesting and most natural wetland ecosystem within the City of Elmina development. This pond supported the richest bird and Odonata communities in March 2019, and in June 2020 this legacy was continued. Water quality within this pond was visually extremely good, with clarity to the bottom sediments and high visibility, giving the pond a high aesthetic value. If this water quality and visual aesthetic can be maintained following the completion of the City of Elmina development, this lake has high potential to be the "jewel in the crown" of City of Elmina.

Figure 77: Blue and pristine water attracts diverse dragonflies and bird species.

The site is fringed on its north-western edge by a shelterbelt of mature and semi-mature *Acacia* woodland and other scrub, which provides a buffer between the pond and the Sungai Subang and against noise pollution from the adjacent Guthrie Corridor Expressway and Elmina junction. Without this belt of trees, this pond would be exposed to significant noise pollution and disturbance and it is unlikely that it would continue to support a population of Lesser Whistling Duck (*Dendrocygna javanica*) and Purple Heron (*Ardea purpurea*), as well as the otters observed here by SDPB staff and contractors. All these species require peaceful and un-disturbed habitats to survive at City of Elmina.

 

Figure 78: The Lesser Whistling Duck (left) and Purple Heron (right) sighted at Pond 4.

The zone along its south-eastern perimeter contains some mature Acacia woodland, but a wide zone, of about 100m has been cleared in the recent past and has now been colonised by an open scrubby vegetation dominated by species such as *Dillenia suffruticosa* and *Melastoma malabathricum*. In places, this lake edge remains clear of vegetation, and / or impacted by surface run-off and sediment from the adjacent development zone. The adjacent development zone is ear-marked for a sports complex or sports facility in the City of Elmina development.

It is our understanding that SDP-CoE would like to retain the pristine nature of Pond 4 and request assistance to ensure that this is possible both during and post development.

Issue(s):

1. Despite the beautiful aesthetic of Pond 4, a major issue continues to be the prevalence of the alien invasive tree *Acacia* spp. (at least 2 species) that make up the majority of its woodland buffer-zone. Maintenance of a mature buffer-zone will be essential to ensure that this site remains in its current state. Figure 77 shows the extent of this buffer-zone woodland along the north-western shore, as well as a small area in the south-eastern part of the lake (extreme left of photo).

Figure 79: The *Acacia mangium* spotted at site.

Acacia spp. are a major ecosystem management problem in Malaysia as this introduced alien tree grows and reproduces extremely rapid and can exclude regeneration of understory plants and other vegetation species in its vicinity. This will eventually lead to mono-culture stands of these trees. This creates problems for insect and bird diversity, as few species thrive in these habitats, and levels of biodiversity are inevitably low. In an ideal situation it would be optimal to remove alien invasive plants and replace them with native plant communities. However, the removal of buffer zone around Pond 4 will severely compromise the value of this site through disturbance and noise pollution. Therefore, it is recommended to execute the removal of *Acacia* spp. in phases to maintain a buffer-zone. The suggested approach would be to clear small areas of *Acacia* spp. and supplementary plant the woodland with fast growing, pioneer native tree species such as *Mallotus paniculatus*, *Trema orientalis*, *Macaranga* spp., and *Microcos tomentosa* that can out-compete and shade out *Acacia* seedlings and its young trees (**Figure 80**).

Figure 80: Suggested supplementary plants to be planted *Mallotus paniculatus* and *Microcos tomentosa.*

2. A second major issue relating to Pond 4 is the potential damage from surface run-off of sediments and soil from surrounding land (especially along the south-eastern shore) and especially from the future development zone (sports facility) in the south-east. In June 2020 it was clear that land clearance and exposed soils adjacent to the new development zone were already starting to have an impact on the environment, due to soil erosion and surface run-off. Whilst this had yet to reach the lake shore, **Figure 81** shows the severity and extent of one area of fine, liquid mud that had eroded from the slope and was creeping towards the lake shore.

Figure 81: Several muddy areas are found uphill. A buffer zone or barrier is needed before further construction is done.

This area was less than 30m from the lake shore (**Figure 81**), and it can be envisaged that the impact of such a fine, clay sediment on the water quality in Pond 4 should it reach the lake edge will be catastrophic. It is imperative that sufficient silt traps, silt fences and where ever possible minimal slope cutting and soil exposure is allowed to occur during the development of the surrounding infrastructure at the site, whilst at the same time maintaining the 100m zone of vegetation between the new development and the lake as a buffer. Ideally, water run-off channels from the new development zone should by-pass the catchment of Pond 4 and be discharged directly into the Sungai Subang to ensure the pristine water quality is maintained in Pond 4.

Pond 5 & 6 (twin lakes)

Both Pond 5 and 6 share a similar position adjacent to the Sungai Subang and a suite of issues (Figure 82). Both ponds are fed by drainage in-flows from surrounding housing developments and roads, and to some extent precipitation, both ponds have exit gates that discharge into the Sungai Subang when water levels within each pond exceed a set parameter.

Figure 82: The current conditions of Pond 5 & 6 during the survey.

Issue(s):

1. Major issue for pond 5 is related with the water level management. During dry season, the water level is too low causing the fringe of the pond dried out and not suitable for wetland plants to survive.

Figure 83: Low water level at Pond 5.

2. The second issue identified on site is the steep slope of the pond. The survival of the wetland plants also depends on the slope on the edge of the pond. With steep slope, water level plays very crucial role in order to create a suitable environment for the survival of the wetland plants. Water at the site is also murky due to fine suspended sedimentation and algal blooms.

Figure 84: The steep slope of pond edge.

3. The third issue observed on site was the accumulation of rubbish and sediment near the runoff outlet/gate. The accumulation of rubbish and algae at sight indicated that there is no active

maintenance in place. The team also observed the poor water quality at site and this is mainly due to the lack of macrophytes planted at the correct planting zone to filter the runoff (Figure 85 and Figure 86). This has caused the water at the site murky. With the accumulation of sedimentation and no proper filtration at site, water quality of the pond will deteriorate and further threatening the living organism at pond 6.

Figure 85: Rubbish accumulation in the area.

Figure 86: Unhealthy macrophytes at the dry fringe near the runoff outlet.

Wetlands in Elmina West

Pond 2

This pond has been created specifically as a key wetland feature within the Elmina West development – it will perform two primary functions, firstly as a storm water run-off and sediment retention basin to collect and channel water away from the housing development and into the Sungai Buloh basin; and, secondly, as a recreational feature for local residents to enjoy their environment. In addition, this pond will ultimately provide habitats for interesting wildlife (birds, fish, butterflies and dragonflies), and, as such will provide additional services such as environmental education for local residents. The management and maintenance of this pond needs to reflect these two primary functions and ensure that both can be maintained in the long term.

Figure 87: Lotus lake at Pond 2.

In March 2019 the area had been sculptured into a kidney-shaped basin, but remained empty of water. In June 2020, the pond was filled with water and had been planted with some aquatic plants – notably a small bed of sacred lotus (*Nelumbo nucifera*) and Water Lilies (Nymphaeaceae), and small stands of common cat-tail (*Typha angustifolia*) adjacent to the inflow channel (either through natural colonisation, or the remnants of a wider planting). The hydrology of this pond is reliant on two sources – the majority from "grey water" in-flows from the adjacent housing and road drains; and, from precipitation. At least one of the two in-flow channels is fitted with a gross pollutant trap (GPT). This pond drains directly into the Sungai Buloh via a water gate on the north shore of the pond.

Issue(s):

1. The water quality within this pond was considered to be fairly poor, with signs of high sediment loads and some eutrophication (algal blooms). This is not surprising as the pond is less than 1 year old, and needs time to establish and reach the "mature" stage of a wetland ecosystem; but, also is due to its primary function as a storm water run-off and sediment retention basin. Some effort has been made to vegetate the pond (either for aesthetic purposes, or to use

natural aquatic vegetation to filter the water). **Figure 88** below shows how effectively even a narrow band of *Typha angustifolia* vegetation can trap and prevent excessive sediments form entering the pond from the inflow channel. Another indicator of poor water quality was the presence of the dragonfly species Ditch Jewel (*Brachythemis contaminate*) within the pond (Figure 89), this species is commonly found inhabiting water of poor quality (many species of Odonata are sensitive to water quality as their larval development relies on water quality – thus they may be used in certain situations to rapidly assess water conditions).

Figure 88: Existing plant filters sediments and rubbish from the runoff.

Figure 89: The dragonfly - Ditch Jewel (*Brachythemis contaminata*) sighted at pond.

Pond 9

Pond 9 in Elmina West is the main feature lake of the Community Park development. The site is a landscaped park-scape including two lakes, manicured lawns and scattered trees, with visitor infrastructure including shelters, viewing platforms, picnic areas and running and cycling tracks. Many of the planted trees are mature or semi-mature specimens of native, tropical forest trees. The trans-planted trees are on the whole growing well.

Figure 90: The current condition of Pond 9 during the survey.

The pond is fed by surface run-offs and exits into the Sungai Subang which discharges under the main Guthrie Corridor Expressway and continues through Elmina East (adjacent to Elmina East Pond 4). The pond is sinuous in form, more or less following the floodplain valley of the river, and is approximately 1300m long and up to 50m wide. The system is orientated within an East-West direction at the centre of the City of Elmina development. The central pond is steep-sided with artificial edging around most of its' perimeter. Despite this, there is some development of a littoral fringe of aquatic vegetation, especially where the central cement walkway crosses the lake and creates a barrier to waterflow.

Issue(s):

1. During our visit to Pond 9, the edge of the pond was dominated by overgrown grasses instead of desired macrophytes - *Typha* sp (Figure 90 and Figure 91). The overgrown grasses may be due to the low water level of the pond and this has promoted the undesired grasses and weeds success the *Typha sp*.

Figure 91: The undesired weeds has outgrown the desired macrophytes sighted at Pond 9.

2. Another issue observed at this pond is the excessive suspended sedimentation which have formed 'small islands' of sedimentation in the middle of the pond. These small islands are mainly due to the over sedimentation from water runoff.

Figure 92: Accumulation of sediment from the runoff causes small islands to emerge.

Pond 10

Despite the small size, Pond 10 is one of the most interesting within the City of Elmina development. The "pond" actually consists of two small flood retention ponds adjacent to (south-east of) the Sungai Subang where it discharges from the Bukit Cherakah Forest Reserve. Due to its' location at the edge of the forest the site has potential to attract different biodiversity to the other ponds, as species of birds in particular using the forest edge may move into this area once the development matures.

Figure 93: The current condition of Pond 10 during the survey.

The ponds were probably historically connected to the Sungai Subang as part of its floodplain wetlands. However, they are now separated by a high retention bank and linked through sluice gates and function as run-off and drainage collection ponds. The two ponds are at differing heights which creates a cascading flow, with terraces between the ponds to aerate the run-off water before it exits into the Sungai Subang.

Issue(s):

1. Both ponds are shallow (probably less than 2m in depth) due to sedimentation over the years, and both have developed healthy fringe of littoral aquatic vegetation consisting mostly of sedges (*Carex spp.*) and arrowheads (*Sagittaria spp.*). However, several invasive species such as *Acacia sp.*, Giant Mimosa. (*Mimosa sp*.) and Water Hyacinth (*Eichornia crassipes*) were spotted at the site. The upper (westernmost) pond has a small island developing at its western end, and this is being developed into a larger island in the hope of attracting birds. Even so, the tree in the middle of the small island is not in a good condition.

Figure 94: The sighted invasive plants, Giant Mimosa (blue circle) and water hyacinth (red circle) at Pond 10.

Figure 95: Condition of the tree at the small island.

Figure 96: Wild grass and other vegetation started to grow in between *Limnocharis sp.* and *Eleocharis sp.*

Sungai Subang

Multiple observations were carried out along selected stretches of Sungai Subang – namely Elmina West (pond 9 & 10), Elmina East (pond 6). The Sungai Subang flows from Bukit Cherakah Forest Reserve and cuts through Elmina West heading towards Elmina East.

Close to the edge of the forest reserve, the water flowing out from the forest reserve is generally clear though there were parts of it where the water was muddy. It is most likely due to erosion of exposed soil from the surrounding oil palm plantation and construction activities. Cows have been seen grazing along the river which causes minor desertification through grazing activities and further contributes to sediment run-offs.

Figure 97: The Sungai Subang next to Pond 6.

Travelling further down, the discolouration of Sungai Subang is especially apparent in the Elmina Central Park area. This is no doubt due to sediment run-off from construction activities in the surroundings. Throughout the area, there were no visible silt traps noticed nor were there any form of protective barrier which would reduce sediment run-off from the construction site to the river. Steep slopes and the lack of fringing vegetation to slow water flow and trap sediments also contributes to the cause for the milky brown colour of the river especially during heavy rainfall.

Sungai Subang receives water from the surrounding ponds and surface run-offs of varying sources which includes but not limited to oil, grease, fertilizers and nutrient run-offs. Without proper treatment or the presence of wetland vegetation to absorb the excess nutrients in the water, it will eventually cause eutrophication – a state where excessive nutrient content in the water body induces the growth of algae. This may result in oxygen depletion of the water body which is detrimental to the aquatic ecosystem further downstream.

Issue(s):

1. There are very few riparian tree species along the Sungai Subang has been observed. During the visit, the survey team observed there are overgrown grasses and climbers along the bank of Sungai Subang. The low avifauna biodiversity along Sungai Subang may be due to the lack of riparian trees which can provide shelter and food for the avifauna.

Recommendations

Recommendation 1: On the need to reduce sediment and pollutant loads into the ponds

It is recommended that a programme of supplementary planting of suitable water plants (specifically *Typha angustifolia*) perpendicular to the in-flow channels be initiated in order to reduce the amount of sediment and grey water inflows into the pond.

This can be clearly shown at Pond 2 of Elmina West where the existing *Typha angustifolia* beds that already helps to filter floating rubbish and sediments (and filter nutrients from grey water). Such macrophyte zone should be retained and enhanced (Figure 88). Supplementary planting should be carried out during periods of low flow (dry season), and using fairly mature plant stock, to enable rapid establishment of a strong root zone. Planting should not be done during the wet season as newly planted vegetation will be washed away. Planting of new *Typha* stock should always been done within the zone of inundation, at water depths of up to 0.5m deep, not in dry or periodically dry situations. However, the area must be managed regularly to remove rubbish.

Recommendation 2: On the need to reduce gross pollutants entering the pond

Ensure that both in-flow channels are fitted with Gross Pollutant Traps (GPTs), and ensure that these are cleaned and maintained as part of the SOP for maintenance and services. This will prevent unsightly, floating garbage and rubbish within the pond as was observed in June 2020 (Figure 85).

Recommendation 3: On the need to develop detailed and specific SOPs for pond maintenance and management

Ensure that the Standard Operation Procedure for maintenance and services includes provision for a phased approach to dredging and cleaning operations. After 3 to 5 years (it could be longer if recommendation 1 and 2 are implemented) it is inevitable that the constructed wetlands within City of Elmina will contain significant deposits of sediment and these will need to be dredged or cleared out.

Provision for this is made in the design of a series of concrete ramps leading into the pond to allow access of heavy machinery when dredging is required (Figure 98). Dredging is a necessary management and maintenance operation for storm water retention ponds such as this, but it is also a highly destructive activity that will inevitably remove any well-established plant beds that act as filters, improve water quality and provide habitats for biodiversity. So, it is recommended that dredging takes place using a phased and rotational approach.

Figure 98: The concrete ramp for maintenance at Pond 2.

For example, it is recommended to divide **Pond 2** into three zones (each adjacent to its own access ramp). In Year 1 (depending on sediment accumulation and need) zone 1 is dredged completely; and, zones 2 and 3 remain untouched. In Year 2 zone 2 is dredged, with zones 1 and 3 untouched; and, in Year 3, zone 3 is dredged with zones 1 and 2 untouched. In this way, the established plant beds and biodiversity associated with them will have time to re-colonise the newly dredged ponds and not have to start the re-colonisation or replanting process from scratch. Furthermore, as part of the SOP on maintenance and services, during the dredging process for each zone, the contractor must be required to remove and maintain significant beds of well-established aquatic plants. For example, 30% of existing plant beds can be lifted from the pond using an excavator, including an intact root zone, following a process of washing excess soil from the root mass, these plants can then be placed into a new location within the pond. Specialist help may be required to supervise the contractor to undertake this task properly and provision should be made for this. This type of sensitive and adaptive management allows for re-crafting of the vegetated wetlands within the pond, for instance, by relocating plant beds near in-flow channels or along the perimeter of the pond.

Recommendation 4: On the need to reduce in-pond nutrient loading

Apart from a reduction in nutrient loads from in-flow water, it is also possible to reduce in-pond nutrient loads through planting of aquatic plants that will absorb nutrients via their root zones and systematic removal of plant biomass as part of a managed cycle of pond maintenance. This is partly alluded to in Recommendation 3 related to developing detailed and specific SOPs for pond maintenance and management above.

The practice of constructed treatment wetlands has clearly demonstrated that these types of systems can play a role to mitigate the impacts of urban wastewater and run-off on lakes, ponds and rivers. In Malaysia, the Taman Wetland, constructed at Putrajaya in the late 1990s remains one of the World's largest and most successful constructed wetland, designed to intercept nutrient and sediment in-flows and remove these nutrients from the system through regular maintenance. There is an opportunity to create similar functioning wetlands at City of Elmina.

Apart from in-pond supplementary planting of aquatic plants, and the regular maintenance of these plant beds as stipulated in Recommendation 3 above, other forms of nutrient removal from water bodies have been developed globally and may be relevant to City of Elmina. These include the "Floating wetlands" technique that has been done pioneered previously with using *Typha angustifolia* and were proven successful (by Weragoda et al., 2012). *Typha sp*. lends itself to this type of application as it has a well-developed and buoyant root system and can filter and absorb huge amounts of nutrients from the water column. Typically, floating *Typha* beds are used as the primary filter in surface flow waste-water treatment wetlands (SFWTW) and a similar system could be implemented at City of Elmina on all be it a much smaller scale.

Recommendation 5: On the need to manage fish populations

A major issue with many urban storm water run-off and sediment retention ponds (especially in the tropics) is eutrophication. Eutrophication is the process by which excessive algal blooms dominate the water column and reduce levels of light, oxygen and habitat for other plants – often leading to a green algal scum rather than a clear water pond. These processes are driven by excessive nutrient loads in the water, sunshine and heat. In many cases, high fish population in the pond is one of the contributing factors to eutrophication and algal blooms, especially in shallow, tropical ponds.

Fish are often introduced to urban wetlands to "enhance" the pond life, but in many case they can lead to reduced pond life and eutrophic states. Fish in the family Cyprinidae (carps) are typically one of the drivers of eutrophication as they produce several hundred thousand eggs per female per year, and upon hatching these 0+ and 1+ fingerlings are responsible for consuming most or all of the zoo-plankton within a pond. Without a population of zooplankton to consume single celled algae, the algae will bloom. In addition, the mature fish are bottom feeders and continuously stir up the bottom sediments within a pond, re-suspending sediments and nutrients into the water column to prolong the eutrophication process. Exotic fish species in Malaysia, such as Tilapia (*Oreochromis spp*.) from Africa can also contribute to eutrophication in a similar way to carp.

It is therefore important that the species and numbers of fish introduced into such shallow urban wetlands be managed properly. It is recommended that an annual or bi-annual survey of fish populations be undertaken within this and other ponds at City of Elmina to determine the presence and population structure of problem species. Removal of breeding age Cyprinidae, and 0+ and 1+ populations, as well as systematic removal of alien, invasive Tilapia is recommended. Stocking of fish populations with a balance of predatory and non-predatory species, and a reduction of herbivorous species (as they will consume the beneficial filtering plants) is also recommended.

Recommendation 6: On the need to maintain Pond 4 as a pristine wild area within the City of Elmina development.

It is exceedingly rare that a lake ecosystem such as Pond 4 can be found in within an urban or peri-urban setting in Malaysia. The visual quality and clarity of the water, the peaceful aesthetic of the site and the wildlife that the site supports all point to the conclusion that this lake should be maintained as close as possible to its current state and feature as a showcase of SDP-CoE efforts to conserve and protect the environment for future residents of City of Elmina.

Comparison between Pond 4 and the Central Park Lake in City of Elmina shows how difficult it is to maintain a beautiful focal wetland within a housing development – invariably lakes and ponds within development areas are treated as “sinks” and used as retention ponds to trap sediments and pollutants from drainage channels. These retention ponds are often considered difficult to manage, become silted up, polluted and over grown with vegetation. In their deteriorated state these ponds may provide suitable breeding sites for Aedes mosquitos and other pests.

In order to ensure that Pond 4 remains in good condition and provides recreational, aesthetic, biodiversity and other services for the community, it is imperative that the top management within SDP-CoE and City of Elmina agree on the need to protect and conserve this area and remove any potential negative impacts of the proposed adjacent development zone. As such, the following recommendations on preventing sediments from entering the lake; the maintenance and management of the buffer-zone and the strict monitoring of drainage channels and run-offs from surrounding areas must be agreed and enforced.

Recommendation 7: On the need to prevent sediment and soil surface run-off from entering Pond 4

It will be extremely difficult to maintain good water quality and overall environmental quality around Pond 4 once the proposed sports facility development starts to be implemented. However, with a high-level policy decision, and commitment from the top, it should be possible to implement the following sub-recommendations:

a) Maintenance and management to enhance the vegetated buffer-zone around Pond 4. This should include the woodland buffer-zone between the lake and the Guthrie Corridor Expressway; and, the previously cleared buffer area between the lake and the proposed sports facility (to the south-east).
b) Maintenance and management of the Acacia dominated woodland buffer-zone will include a management plan to remove and replace Acacia species with native fast-growing pioneer tree species. This will take place in a phased approach, to ensure that the integrity of the woodland buffer-zone is maintained at all times. Ultimately, the objective will be to replace as much of the mature Acacia woodland with mature native trees and shrubs. It will be necessary to map current extent of the woodland buffer-zone, identify areas for small-scale clearance and supplementary planting, establishment of tree nursery, and SOPs for management of the site.
c) At least 100m of vegetated buffer zone should be maintained between the proposed sports facility development and the lake edge. Existing vegetation may need to be supplementary planted to improve the function and aesthetic of this buffer, and in the long-term it is recommended that this area be ear-marked for development as a “nature park” or “nature education zone” within the City of Elmina. This site currently contains several micro-habitats (small habitats) such as small ephemeral wetlands that increase the biodiversity found within this site – maintaining these micro-habitats will be an important facet of the site, and provide added value for education and recreation.

Figure 99: Microhabitats such as this is sighted at Pond 4. Educational signage could be made here for community education to identify dragonflies and birds.

d) Slope management to prevent any further cutting of soils or pushing of soils down the slope from the road reserve (in the south-east) into the 100m buffer-zone will be necessary. In June 2020, in several places along the road, soil had either been dumped down the slope of the road cutting, leading to significant soil erosion events and surface run-off creeping towards the lakeshore. During times of heavy and intense rainfall, it may only be a matter of time before these sediment plumes are discharged into the lake. This would severely, negatively impact the water quality of Pond 4.

e) When further land clearance and earth moving within the proposed sports facility development site proceed (currently delayed due to Covid-19 pandemic and MCO orders), it will be necessary to strictly enforce drainage and surface erosion mitigation measures. For instance, all development areas and slopes facing Pond 4 must be protected by sediment fences and barriers; sediment traps must be installed and maintained along all outlets and drains; and where ever possible ground cover and vegetation should be maintained or planted to reduce surface run-offs.

Figure 100: Sign of soil erosion sighted near Pond 4.

f) Ideally, all drainage culverts and channels from the proposed sports facility development site should be diverted away from Pond 4 and discharged directly into the Sungai Subang (with the premise that appropriate silt and sediment traps, Gross Pollutant Traps and other measures are applied).

Recommendation 8: Towards an active water management system to improve environmental services from Elmina's water retention ponds

Currently most of the ponds at City of Elmina are typically function as drainage water retention ponds. Water follows into the ponds from surrounding housing and road areas via drains, and the water is statically maintained within each pond until it exceeds a set depth (around 2m). Then it flows via an exit sluice into the Sungai Subang. During times of excessive or very heavy rainfall, ponds may fill up, but should never achieve maximum capacity or over flow, if they have been engineered correctly. The volumes of water discharged from the exit sluice during times of heavy rainfall, should exceed the in-flows when the water depth is significantly higher than the 2m depth established at the over flow.

These types of water retention basin are rarely interesting for biodiversity or aquatic plants. They require periodic de-silting to remove accumulated sediments and restore designed capacity for retaining water, and most often this process of de-silting will destroy aby habitats that may have developed in time.

Natural wetlands are categorised by their natural abilities to absorb and discharge water through their system (hydrological flows). These flows are usually characterised by periods of flooding and periods of drought, during corresponding wet and dry seasons or event. These seasonal event result in fluctuating water levels with natural wetlands, and it is these fluctuations in water levels that often make wetlands significant for biodiversity, fish and other productivity, flood control, etc.

Within a setting such as City of Elmina, is it possible to use the characteristics of natural wetlands to make the man-made water retention basins more interesting for wildlife and people living with City of Elmina? It is possible, but requires an accurate data set and understanding of the hydrological flows though the various ponds and into the Sungai Subang. By creating or mimicking naturally fluctuating wetlands it is possible to increase edge habitats (aquatic vegetation) and attract more wildlife into the ponds at City of Elmina. It will be necessary to appoint, “water managers” on site, who in tandem with local resident groups, could draft the water management protocols and SOPs to create a more natural wetland ecosystem.

Conclusion

This report aims to provide an overview of the status of CoE waterbodies from a wetland ecologist perspective. It also aims to highlight issues which may arise and provide recommendations which may be beneficial for the development of CoE and the natural environment in the long run though many of the suggestions is still up for discussion. There are two main types of freshwater wetlands located within the City of Elmina development – rivers and their floodplains; and ponds or small lakes.

The Sungai Subang runs through much of the middle of the development in a South-West to North-East direction. Its floodplain forms a wetland corridor through City of Elmina. Over time, the floodplain has been straightened, modified and embanked, in order to modify water flows and control flooding along this sector. However, the floodplain still maintains its basic function as a flood inundation zone and water storage and release mechanism along the length of the river. Associated with the floodplain are numerous small ponds and lakes – some of these may be of natural origin, and others may have been excavated more recently as flood water retention ponds and run-off retention ponds.

In the various ponds, water status is a variable, with those ponds directly linked to the rivers likely to be also nutrient rich and turbid, in some pond's excessive growth of algae and water plants indicates high nutrient loading and, in some cases, eutrophic status. In most of these ponds' levels of land and vegetation clearance within the immediate catchment was high, leading to excessive sedimentation and turbidity. The exception to this is Pond 4 in Elmina East that contained clear water with little suspended sediment, probably due to its wooded catchment, no obvious connection to the Sungai Subang and lack of recent development around its periphery.

The most diverse and interesting site within City of Elmina in March 2019 was Elmina East Pond 4. This site has the lowest levels of disturbance within the site, and development of adjacent areas has yet to have a major impact on remaining habitats and waterbodies. This has led to development of a quite mature secondary woodland fringe and good water quality. There is also need for further discussions on how to proceed for Pond 4 of Elmina East and Pond 10 of Elmina West on minimizing construction impacts at these sites as these two ponds show the highest potential for maintaining the naturalness of the wetlands.

With given time and effort, it is believed that CoE will be able to achieve its goal of creating healthy and functioning wetlands that will serve its purpose of providing its residents with a place of well living.