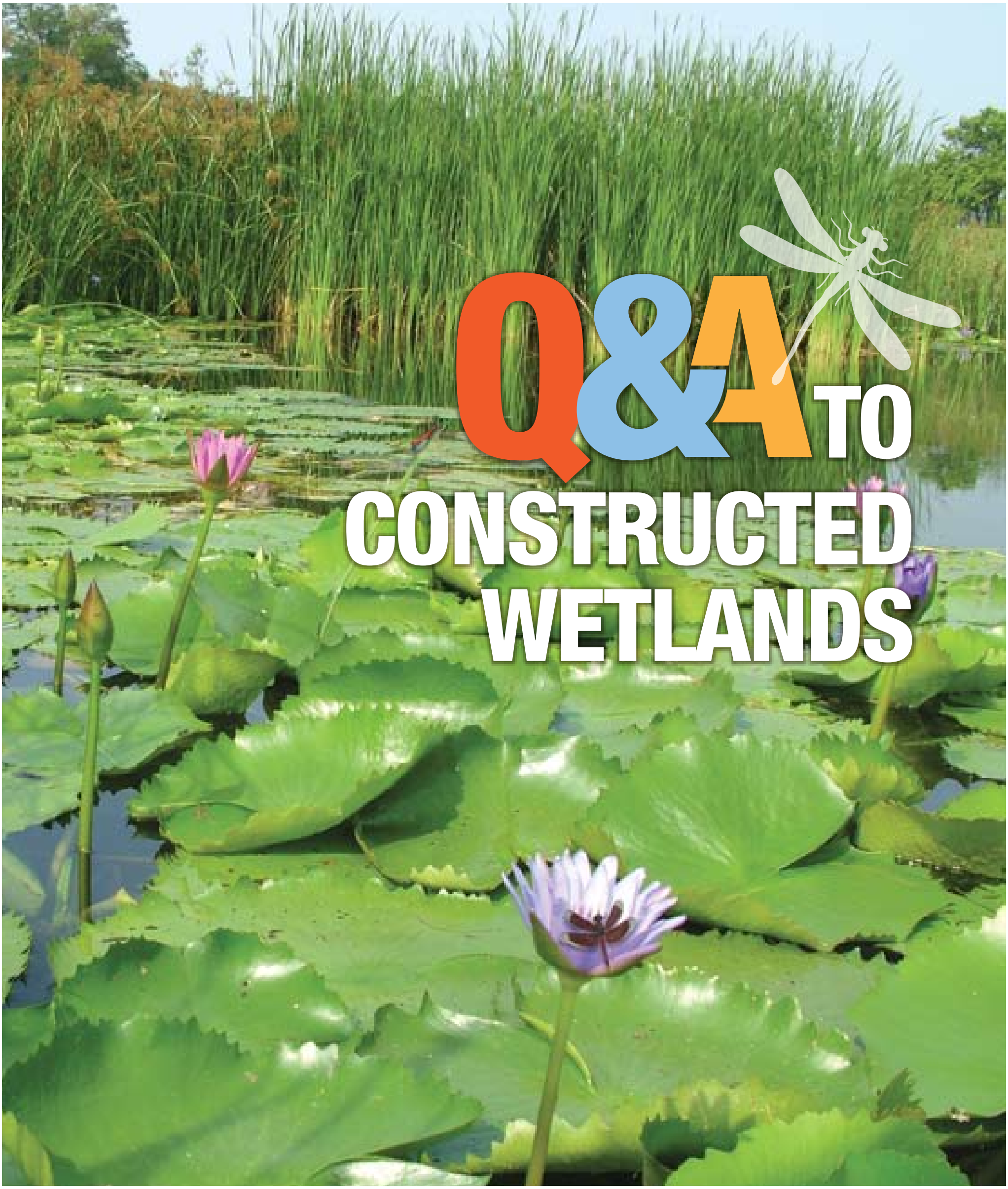

Q&A TO CONSTRUCTED WETLANDS

NRE

NAHRIM

WETLANDS INTERNATIONAL

Q&A TO CONSTRUCTED WETLANDS

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NRE NAHRIM WETLANDS INTERNATIONAL

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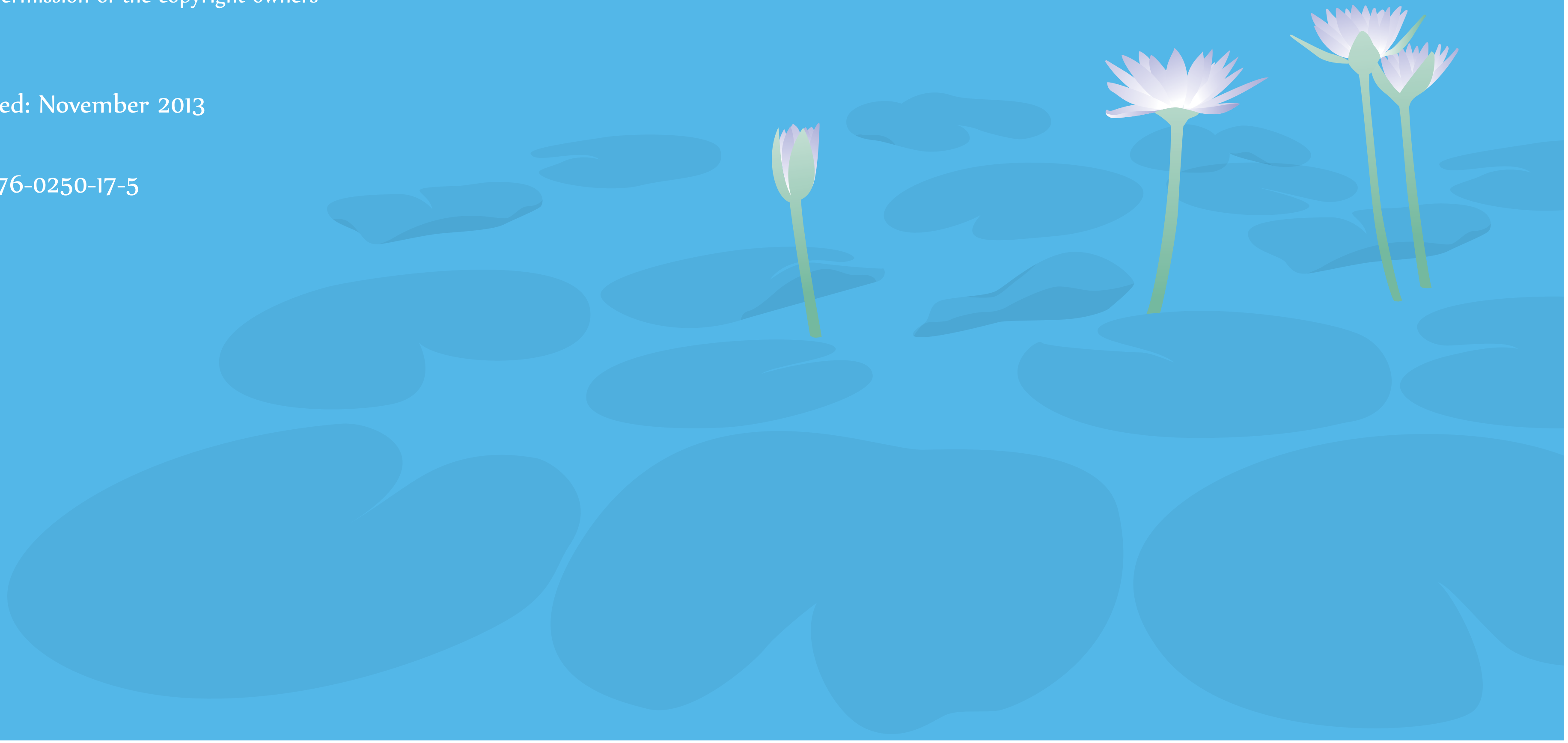

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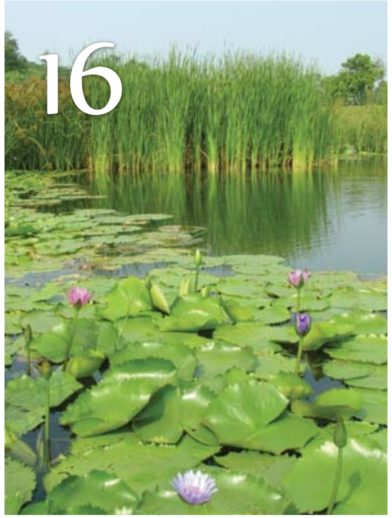


Foreword

Wetlands play an important role in sustaining biological diversity and they also perform vital functions such as water purification, nutrient retention, maintenance of water tables, storm protection, flood mitigation, shoreline stabilisation, erosion control and groundwater recharge.

Wetlands can be classified into three major categories: Marine and Coastal Wetlands, Inland Wetlands and man-made Wetlands (also known as Constructed Wetlands). A Constructed Wetland is a man-made structure created to perform some of the functions of a natural wetland, such as filtering wastewater and polluted stormwater runoff before it enters the local waterways.

Wetland environments were considered wastelands which were drained, filled and converted for commercial, residential or agricultural use. This meant that stormwater and wastewater could no longer be treated through the natural wetlands, instead of piped directly into local waterways through a system of man-made concrete drains.

Urban stormwater pollution is now the biggest threat to our local waterways. During and after a storm, runoff gathers discarded litter, garden waste, sediments, oil and grease from the urban catchment and transports these pollutants directly into local waterways such as urban recreational lakes. This has became one of the leading reasons for water quality degradation of urban man-made lakes in Malaysia. Constructed wetlands are now seen as an economical and effective option to help combat this problem. Constructed wetlands are designed to aid in the filtering process of waste-water and stormwater pollution, as well as offering an aesthetic and environmentally pleasing solution to an otherwise complicated issue.

A constructed wetland project was recently undertaken by the National Hydraulics Research Institute ofMalaysia (NAHRIM) at Tasik NAHRIM which is located within NAHRIM compound. The objective of this project was to rehabilitate the existing wetland cells located at the north-east side of Tasik NAHRIM through construction of proper wetland cells which is now function as a filtration and pollution control medium to improve the water quality of the lake. The project involved cooperation between NAHRIM, Wetlands International and Perbadanan Putrajaya.

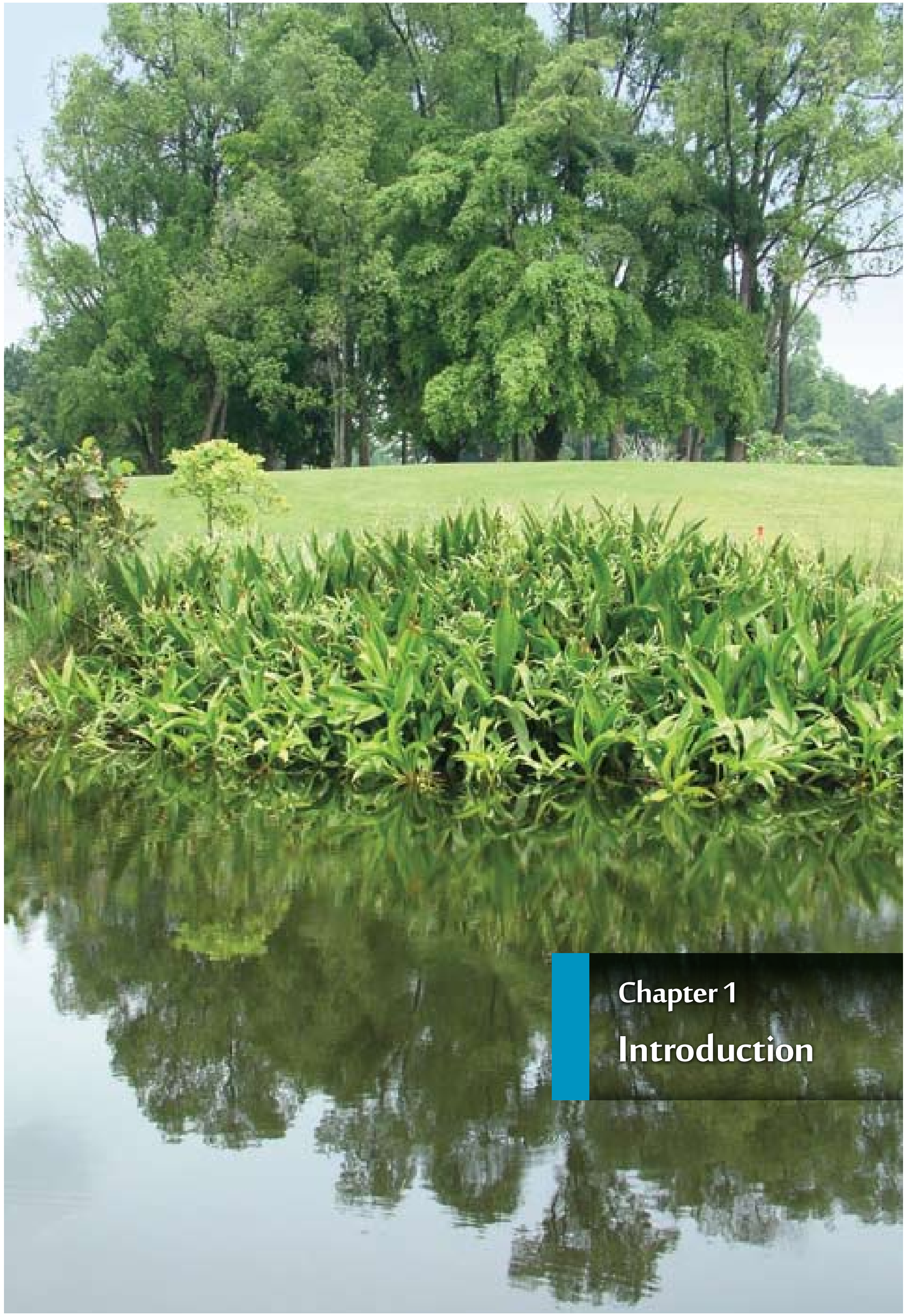
This Q&A booklet on Constructed Wetlands aims to increase the understanding of constructed wetlands and how they function. It is a first step in encouraging the implementation of natural remediation techniques to improve water quality of lakes (especially urban recreational lakes).

The production of this publication would not have been possible without the commitment and dedication of many organisations and individuals (duly acknowledged elsewhere) whose knowledge and expertise was essential to the success of the project. I would like to express my appreciation and thanks to all concerned.

Ir. Haji Ahmad Jamalluddin bin Shaaban

Director General
National Hydraulic Research Institute of Malaysia (NAHRIM)

Ministry of Natural Resources and Environment (NRE)



Chapter 1
Introduction

Constructed wetlands are artificial wastewater treatment systems consisting of shallow ponds or channels which have been planted with wetland plants, and which rely upon natural microbial, biological, physical and chemical processes to treat wastewater.

1 What are constructed wetlands?

Constructed wetlands are artificial wetlands that mimic the filtration functions of natural wetlands. They are basically shallow pools that collect wastewater, mostly stormwater or runoffs from industrial or residential areas, filter it and release it into the environment. The filtration occurs in a natural way; water flows through the constructed wetland slowly, plants filter out or absorb the harmful nutrients and sediments and the filtered water that flows out is a lot cleaner than the water that came in.

Constructed Wetlands are a sustainable and cheap alternative to treat wastewater. Therefore a common use of constructed wetlands is to provide treatment of domestic wastewater from areas such as residential areas, hotels and small businesses.

2 What are the advantages of constructed wetlands?

The treatment of wastewater using the constructed wetlands technology provides several additional advantages:

a) Low operation and maintenance cost - Maintenance costs are low because of less energy, maintenance work and raw materials needed compared to conventional ways of water treatment. The constructed wetlands use natural resources and only require periodic on-site labour and maintenance work.

b) Enhancement of the environment—Constructed wetlands provide an opportunity to create or restore a natural environment where you can even find wildlife. Natural wetlands attract insects, birds, fish and animals. Constructed wetlands can also serve as greenbelts connecting natural areas.

c) Aesthetic value - Constructed wetlands are more pleasant to the eye than normal hardscape structure and mechanical structured water treatment plants. This will be an added attractive factor to visitors who appreciate natural environment; these wetlands can also be made suitable for recreational activities.

d) Research and educational purposes - Constructed wetlands can be used for environmental education, research and training.

e) Compensation for loss of natural wetlands - Since natural wetlands are being depleted rapidly due to land development and for agricultural purposes, the constructed wetlands can help compensate for the loss of these natural ecosystems.

f) Flood control – Constructed Wetland can also act as retention ponds that collect excess water during heavy downpour.

3 Where has the constructed wetland system been applied in Malaysia?

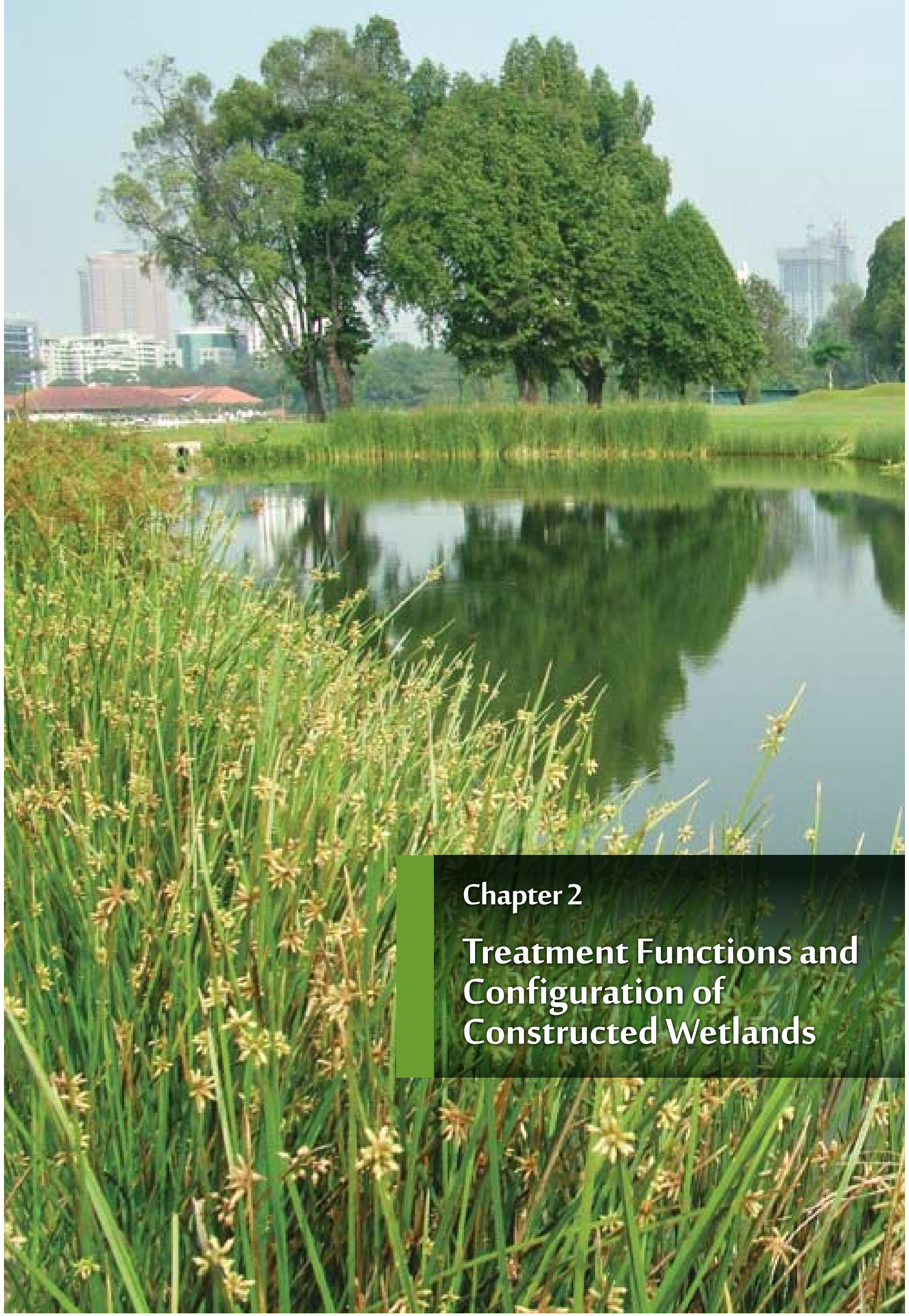
A. Putrajaya Wetland Park – largest constructed wetland in Malaysia, for water treatment, recreation and education purposes.

B. Golf Courses – function in absorbing excessive nutrient and provide habitat for urban wildlife (example: Royal Selangor Golf Club).

C. Public Recreational Lake – provide aesthetic value for public and provide habitat for urban wildlife (example: Desa Park City Waterfront).

D. Lake on research institute premises – provide water filtration and research opportunity in plant species selection for constructed wetlands (example: NAHRIM).

A Putrajaya Wetland Park
B Golf Courses
C Public Recreational Lake
D Lake on research institute premises



Chapter 2

Treatment Functions and Configuration of Constructed Wetlands

Constructed wetland treatment systems can be a reliable and cost effective way to treat wastewater if they are well designed and if the water is not extremely polluted.

1 What are constructed wetland treatment systems?

Constructed wetland treatment systems are systems designed to filter and treat pollutants found in wastewater before it is discharged into the environment. This method uses a combination of wetland plants, soils, gravity, solar energy and microorganisms to remove contaminants from wastewater and to improve water quality. It does not require the use of electricity or chemicals, has minimal operational cost, but requires a large land area.

2 Are constructed wetland treatment systems reliable?

If they are well designed, constructed, operated and maintained, constructed wetlands treatment systems are reliable. It is usually more effective after the wastewater has already gone through some primary or secondary treatment process before entering the constructed wetlands. Various factors need to be taken into account before deciding on the type of constructed wetland, for example the environment (whether industrial, agricultural or residential), precipitation, temperature, soil type etc.

3 What do these systems treat exactly?

Constructed wetland treatment systems can remove most pollutants associated with municipal and industrial wastewater and stormwater. They are usually designed to remove pollutants such as suspended solids, soluble organics, phosphorus and nitrogen. Constructed wetlands have also been used to remove metals, including cadmium, chromium, iron, lead, manganese, selenium and zinc, and pathogens from wastewater.

4 How does a constructed wetland treat wastewater?

A natural wetland acts as a watershed filter, a sink for sediments and precipitates, and a biogeochemical engine that recycles and transforms some of the nutrients. It is the same for a constructed wetland.

Constructed wetlands can even perform many of the functions of conventional wastewater treatment systems like sedimentation, filtration, digestion, oxidation, reduction, absorption, and precipitation.

Wastewater is channelled into a constructed wetland. The flow of water is slowed down by wetland plants/vegetation in the area and also by water control structures such as weirs. Sediments and suspended particles can then settle and sink to the bed of the constructed wetland.

The stems and root system of the wetland plants help to trap and filter these sediments and pollutants. These plants as they grow provide a suitable environment for microorganisms to flourish. These microorganisms breakdown biodegradable material/substances through the decomposition process.

The wetland plants then absorb the nutrients from the soil and use these to propagate and grow. They also absorb harmful minerals such as nitrogen, phosphorus and other compounds from wastewater. By the time the water is released or flows out from the constructed wetlands, it is considered clean.

5 What are the different types of constructed wetland treatment systems?

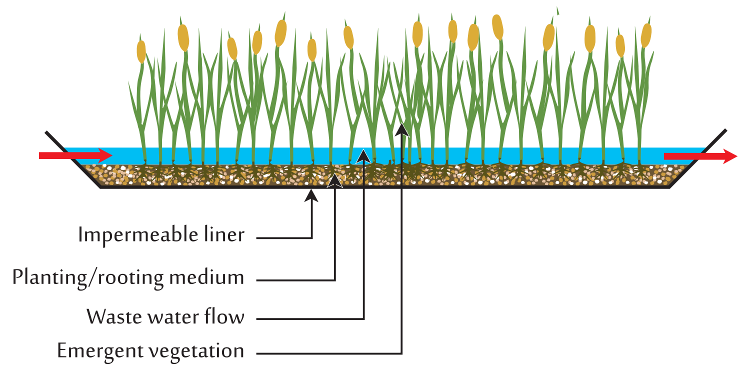
Generally there are two types of constructed wetland treatment systems.

(a) Surface Flow Wetland

A Surface Flow Wetland resembles a natural wetland in the way it looks and the way it treats wastewater. It is a shallow wetland which uses a combination of emergent wetland plants (cattail, bulrush and reeds), floating plants (aquatic sensitive plants, Asian watergrass and white primrose) and submergent wetland plants (water trumpet and water sprite) to treat wastewater.

A Surface Flow Wetland can have open-water areas dominated by submergent and floating plants, or it may contain islands for habitat purposes. These systems can come to exhibit interesting aquatic ecology, attracting birds, fish, insects and animals, and creating an environment that can be converted into parks suitable for recreational purpose.

Surface Flow Wetland



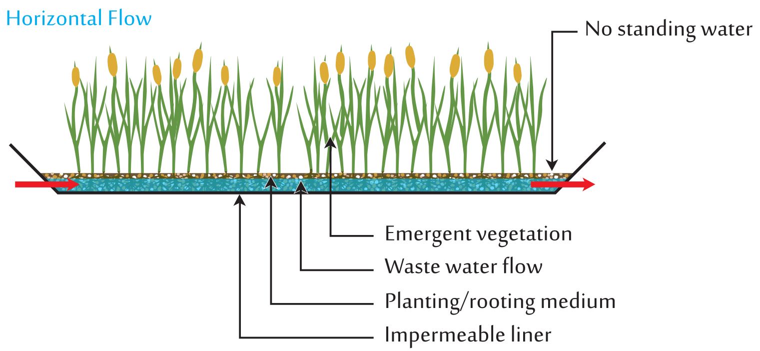
(b) Subsurface Flow Wetland

A Subsurface Flow Wetland is made up of a gravel bed with emergent wetland plants growing on them in most cases.

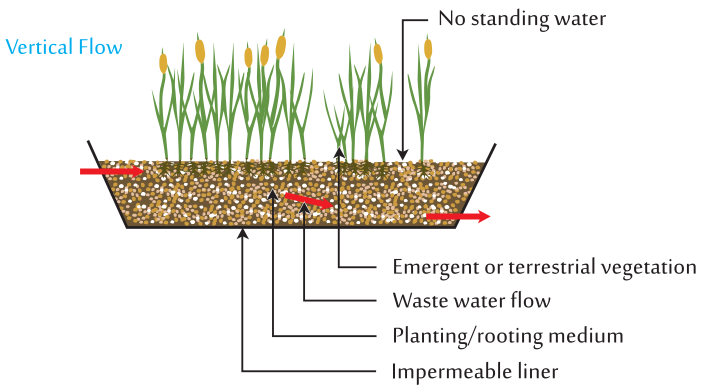
Wastewater flows through this gravel bed and does not rise above the surface. This system is also shallow and contains sufficiently large gravel to permit long-term subsurface flow without clogging. Roots and tubers (rhizomes) of the plants grow into pore spaces in the gravel. They allow microorganisms to breakdown biodegradable material / substances through the decomposition process.

These areas are (almost) mosquito and odour free as water flows below the surface area. The plants also absorb metals and harmful nutrients in wastewater. This system can be subdivided into the Horizontal and the Vertical method. The following diagrams will explain this further.

i) Subsurface Flow Wetland - Horizontal Flow



ii) Subsurface Flow Wetland - Vertical Flow



6 What is the difference between treatment and enhancement wetlands?

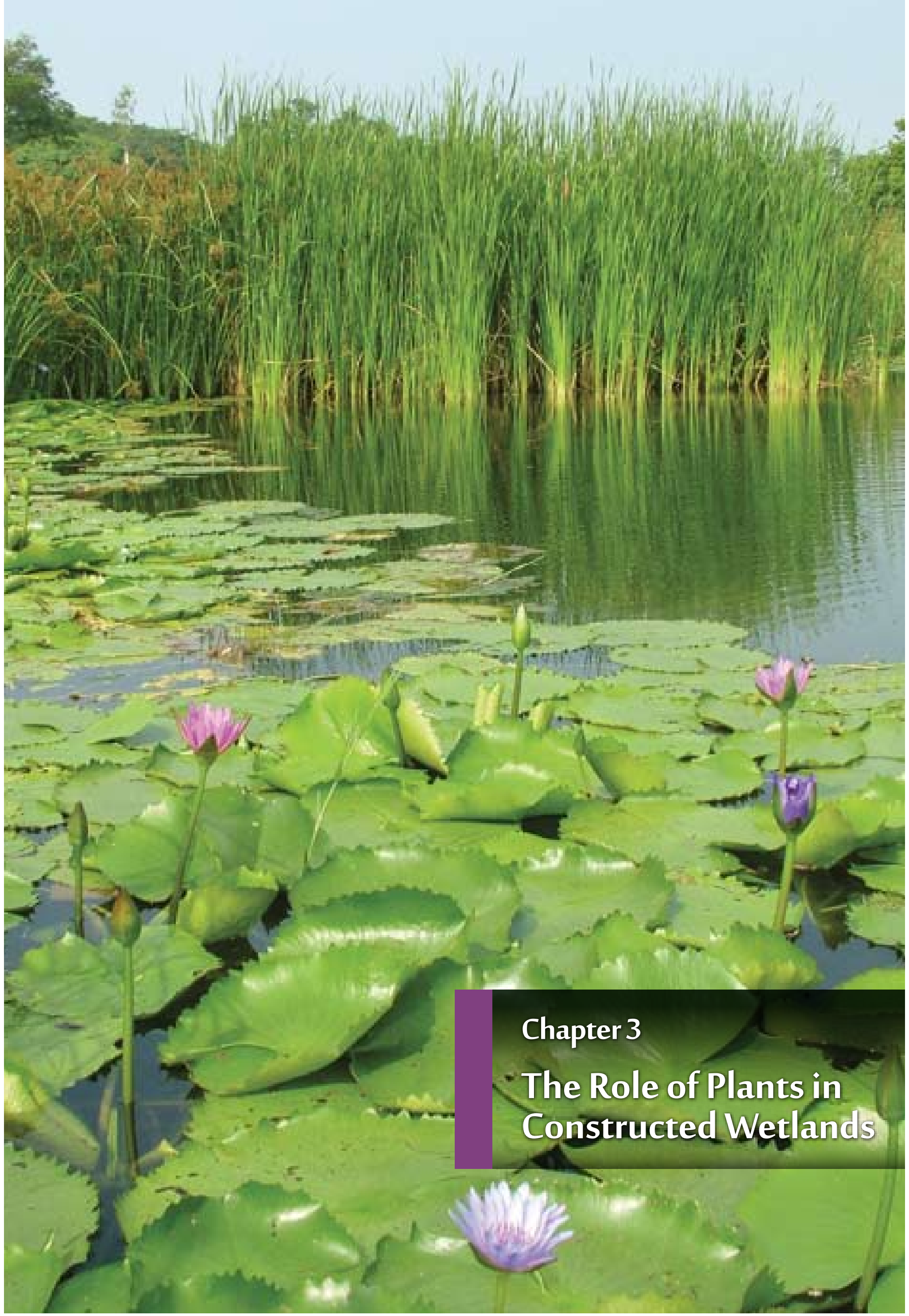
Treatment wetlands are constructed wetlands designed to remove excessive and harmful pollutants from wastewater (municipal or industrial effluents) as well as stormwater runoff.

Enhancement wetlands are constructed wetlands that further treat wastewater before it is released into the environment. They are also referred to as enhancement marshes or polishing wetlands. They are designed with the intention of creating an environment suitable for recreational and environmental education activities. They attract wildlife, birds, fish and other biodiversity. It provides an educational and refreshing experience for visitors to visit parks such as Putrajaya Wetland Park.

Both types of wetland systems can be designed as separate systems, or important attributes of each can be incorporated into a single design with multiple treatment and enhancement objectives.

7 What type of constructed wetland system to choose?

Surface Flow Wetland will provide both wastewater treatment function and enhance the aesthetic value of the environment and provide habitat for wildlife which can then be used for recreational purpose. However, Subsurface Flow Wetland is more efficient in wastewater treatment but less attractive and not meant for recreational use.



Chapter 3

The Role of Plants in Constructed Wetlands

Plants are very important for all constructed wetlands. Plants play a role in cleaning the water. They both take up and retain pollutants and facilitate other cleaning processes to take place by providing a habitat for microbes.

1 What are the roles of the plants in constructed wetlands?

a) The plants provide a suitable area for attachment and growth of microbes and bacteria which help in breaking down pollutants in the water.

b) The physical structures of the plants, like the stems and root system, stabilise the surface of the beds and slow down the water flow, which allows sediments to settle and be trapped, resulting in clearer water.

c) Wetland plants help in the removal and retention of nutrients in the soil and/or water. They do this by absorbing nutrients which they need to grow and these nutrients can be released again when the plants die or are removed when harvested.

d) Improve the ability of the soil to absorb nutrients and toxic effluents.

e) Plants release a variety of organic compounds through their root system which are a source of food for the microbes that aid in the decomposition or breakdown of organic particles.

f) The plants provide a habitat for wildlife and create a green and pleasant environment.

2 What type of wetland plants are used in constructed wetlands?

A combination of floating, emergent and submerged plants is used in constructed wetlands. Different plants have different functions. The table below illustrates the different plants used and their purpose.

Floating Plant Root system either suspended from floating leaves or rooted to bed	The amount of these plants must removed on a regular basis as they will eventually cover the surface of the water and block out sunlight to the lower level of the water, thus effecting the survival of living water organisms and deteriorating the water quality.

Examples

Nymphoides indica (Water Gentian)

Neptunia oleracea (Aquatic Sensitive Plant)

Ludwigia adscendens (White Primose)

Nymphaea nouchali (Water Lily)

Emergent Plants	Stand erect and rooted to bed, upper part of the plants is usually above the water surface. Tolerate changes in water level. These plants can be divided into deep marsh, marsh and shallow marsh.

Deep marsh

Our project experience shows that optimum condition for deep marsh plants is at water depth of 0.3 m – 0.7 m.

Examples

Lepironia articulate (Tube Sedge)

Phragmites karka (Common Reed)

Scirpus mucronatus (Bog Bulrush)

Marsh

Our project experience shows that optimum condition for deep marsh plants is at water depth of 0.1 m – 0.3 m.

Examples

Eleocharis dulcis
(Spike Rush)

Scirpus grossus
(Greater Club Rush)

Typha angustifolia
(Cattail)

Hanguana malayana
(Common Hanguana)

Polygonum barbatum
(Knot grass)

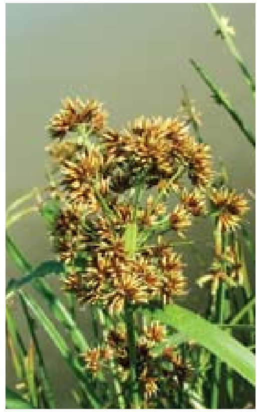
Shallow marsh

Our project experience shows that optimum condition for shallow marsh plants is at water depth of 0 – 0.1 m.

Examples

Phylidrum lanuginosum
(Fan Grass)

Scleria sumatrensis
(Sumatran Scleria)



Rhynchospora corymbosa
(Golden Beak Sedge)

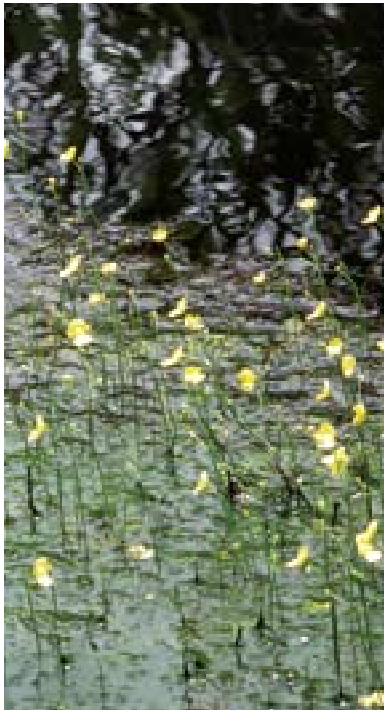
Eleocharis variegate
(Spike Rush)

Eriocaulon longifolium
(Asiatic pipewort)

Submerged Plants	The plants are rooted to the bed, only flowers and leaves occasionally emerge above the water.

Examples

Cryptocoryne cordata
(Water Trumpet)



Utricularia bifida
(Common Bladderwort)

The most important function of emergent and floating wetland plants is providing a canopy over the water column, which limits production of phytoplankton and increases the potential for accumulation of free-floating wetland plants (e.g. white primrose) that restrict atmospheric reaeration. These conditions also enhance reduction of suspended solids within the Surface Flow system. Submergent plants play almost the same role as emergent plants in that they have the capability to absorb large amounts of harmful nutrients, metals and biotoxins. These plants are later physically removed during maintenance or eaten by animals or fish.

3 What planting conditions are required for these plants?

The planting conditions required will differ per plant. For every plant the following needs to be considered: the area required, water level, soil type, temperature and climate, rainfall, maintenance and cost factor.

4 What are the types of wetland plants that should be avoided?

Wetland plants with high proliferation rate such as floaters e.g. *Eichhornia crassipes* (Water Hyacinth), *Pistia stratiotes* (Water Lettuce), *Lemna minor* (Lesser Duckweed) and *Salvinia molesta* (Giant Salvinia) and submerged plants e.g. *Cabomba furcata* (Forked Fanwort) may cause disruption to the natural aquatic ecosystem. These plants will produce a massive mat that will obstruct light penetration to the lower layer of the water column. This will affect the survival of living water organisms thus decreasing the water quality in the long run. Even though these plants have shown ability in removing concentrations of BOD, TSS, Total Phosphorus and Total Nitrogen, it is not advisable to use them, as it involves high maintenance costs to remove these plants continuously on a regular basis. These plant species should only be used in ponds/ structures that are not directly connected to the public waterways.

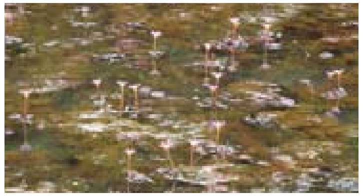
Composting or disposal of these plants has to be handled carefully and appropriately at a suitable locality or facility to avoid them spreading elsewhere.

Invasive wetland plants that should be avoided in constructed wetlands.

Eichhornia crassipes (Water Hyacinth)

Pistia stratiotes (Water Lettuce)

Salvinia molesta (Giant Salvinia)



Cabomba furcata (Forked Fanwort)

5 What are the requirements for wetland plants selection?

a) Capacity to absorb pollutants – Different plants have different rates of heavy metal uptakes. Depending on the BOD of wastewater to be treated, plants with good pollutant absorption are chosen.

b) Tolerance to waterlogged and harsh conditions – It is best to use plants that are tolerant to saturated or low water level conditions so they will continue to propagate and grow healthily, and maintenance costs will be low.

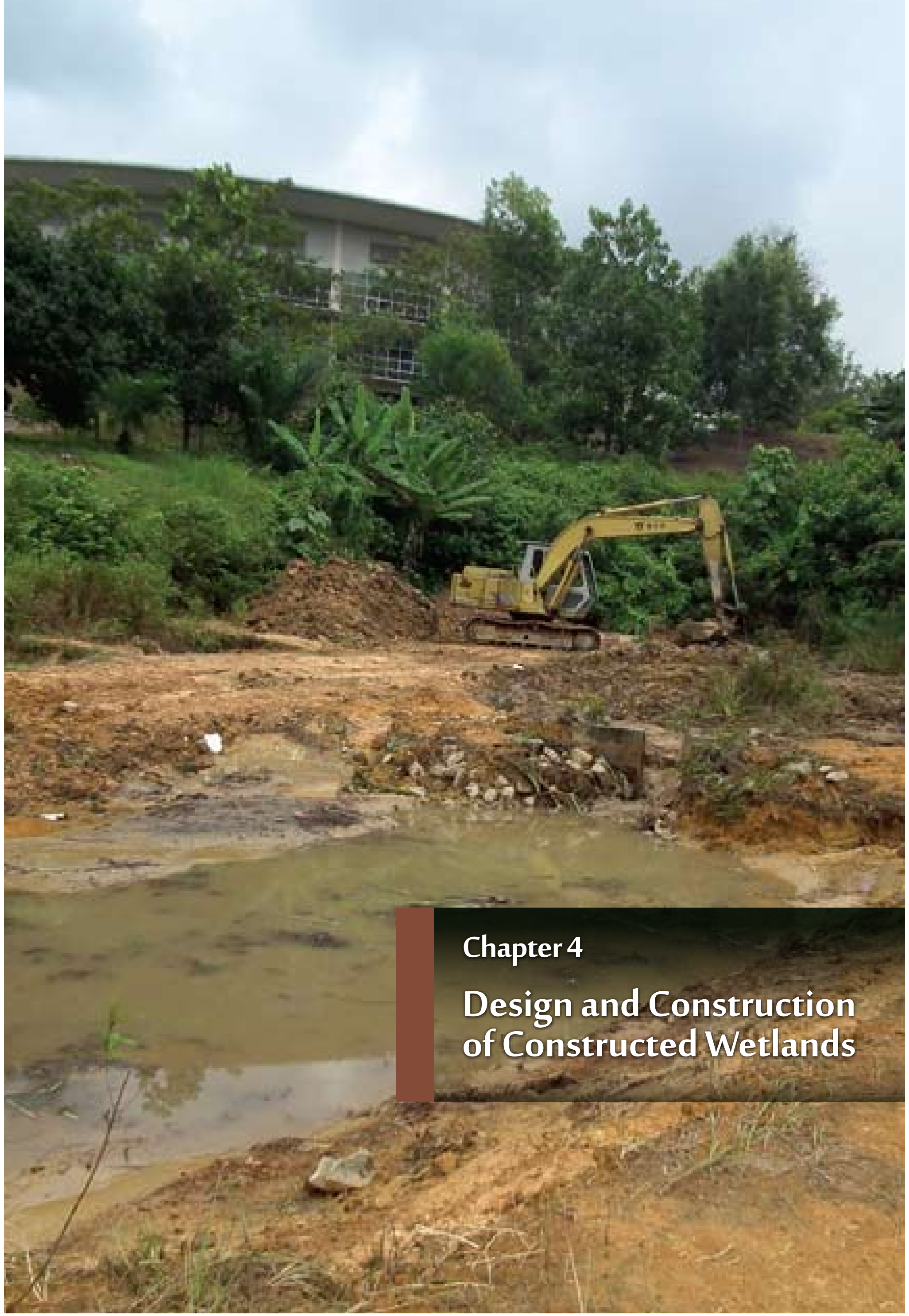
c) Deep root penetration, storing rhizomes and massive fibrous root.

d) Rapid and relatively constant growth rate – how fast can the plant propagate so that the constructed wetland can start functioning. This will save on time and costs of operating the system.

e) Ease of harvesting – How much energy, equipment and time is needed during the harvesting period? To maximize wetland removal of pollutants, the vegetation must be harvested frequently.

f) Indigenous wetland plants – Use of indigenous plants is better compared with introduced species. Cost saving, less chance of turning into a pest and easy to maintain.

g) Aesthetic features – the plants that can make the constructed wetlands look pleasant to the eye. Usually plants that have nice features and flowers are chosen for this.



Chapter 4

Design and Construction of Constructed Wetlands

When designing a constructed wetlands system, various factors need to be taken into consideration. The type of water to be treated, the surrounding environment, how much land is required, soil type, which plays a role in the construction of an effective constructed wetlands system to treat wastewater.

The construction of constructed wetlands primarily involves basin construction, lining of the basin, filling the basin with substrates, constructing inlet and outlet structures, and planting vegetation.

1 How much area is required for constructed wetlands?

A constructed wetland which receives wastewater after going through pre-treatment processes (e.g. primary clarification, oxidation ponds, trickling filter, etc.) requires less area than a constructed wetland receiving heavily polluted wastewater.

The required surface area for a subsurface flow system for the reduction of BOD_5 in sewage effluent can be calculated according to the empirical formula as below:

$$A_h = KQ_d (\ln C_0 - \ln C_t)$$

Where A_h = surface area of bed, m^2
K = rate constant, $m\ d^{-1}$
Q_d = average daily flow rate of wastewater coming through($m^3\ d^{-1}$)
C_0 = average daily BOD_5 of the influent ($mg\ l^{-1}$)
C_t = required average daily BOD_5 of the effluent ($mg\ l^{-1}$)

The value of K = 5.2 is derived for a 0.6 m deep bed and operating at a minimum temperature of 8^0C. For less biodegradable wastewater, K values of up to 15 may be appropriated. Using this formula, a minimum area of 2.2 $m^2\ pe^{-1}$ is obtained for the treatment of domestic sewage. In practice, most design systems operate on the basis of 3 – 5 $m^2\ pe^{-1}$. However, the amount of area required usually depends on the effluent criteria to be met and buffer areas required.

Population equivalent or unit per capita loading, (PE), in waste-water treatment is the number expressing the ratio of the sum of the pollution load produced during 24 hours by industrial facilities and services to the individual pollution load in household sewage produced by one person in the same time.

For practical calculations, it is assumed that one unit equals to 54 grams of BOD per 24 hours.

2 What is involved in the construction of a constructed wetland basin?

Standard procedures and techniques used in civil engineering are applied for the basin construction (earthwork in excavation, leveling and compaction). Most constructed wetlands are created with graded levels (up to 2 -3 levels) along the sides and also with a slight slope in the direction of the flow.

3 Do these basins have to be lined?

This depends on the type of soil and the rock structure of the land. The bottom of the wetland cell should not allow wastewater to seep into the groundwater below and the surrounding environment.

Lining of the basin is required if the permeability of the soil is greater than 10^{-6} m/s. If soils are poorly drained and composed mostly of clay, then lining might not be required. Liner should be selected based on its availability, effectiveness and cost. Proper care should be taken to prevent liner punctures during placement, subsequent construction activity and operation. If the ground contains sharp stones, a layer of sand should be placed beneath the liner level.

4 What is the process of substrate filling?

Substrate filling usually commences after the inlet and outlet have been created. The substrate materials, such as gravel, should be cleaned first to remove dirt and other materials that could clog the empty spaces in between the gravel and render the system ineffective in treating wastewater.

5 Where to place the inlet and outlet structure?

The placement of the inlet and outlet structures depends on the design of the constructed wetlands system, the ideal place differs for horizontal flow or vertical flow design.

Inlet Structure: The perforated pipe should be laid perpendicular to the direct flow in the wetland. The inlet should be designed to minimize the potential of short-circuiting and clogging in media, and maximize an even flow distribution.

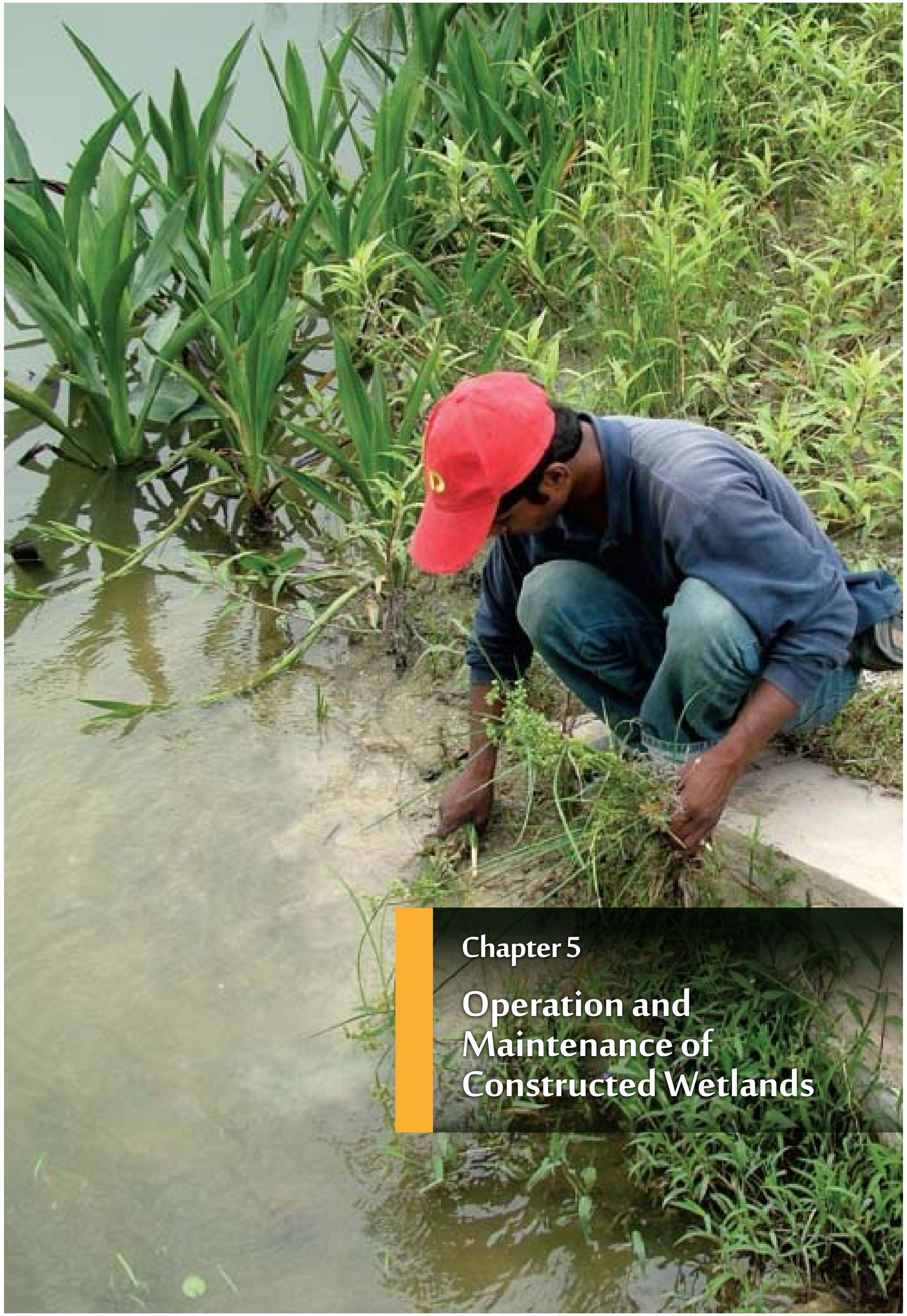
Outlet Structure: The outlet should allow a uniform flow through the wetland and should control the water level.

6 How to plant the wetland plants?

Vegetation can be introduced to a wetland by transplanting roots, rhizomes, tubers, seedlings or mature plants; by planting seeds obtained commercially or from other sites; by importing substrate and its seed bank from nearby wetlands; or by relying completely on the seed bank of the original site.

7 What is the suitable water level for the growth of wetland plants?

The plants need to be planted in the constructed wetland before wastewater is introduced into the system. At the early stage of plant establishment, wetland emergent species should be planted in a wet substrate (but not flooded) and allowed to grow enough to generate a stem with leaves.



Chapter 5

Operation and Maintenance of Constructed Wetlands

After a constructed wetland is created and functioning, it is important to care for the system so that it continues to serve its purpose.

1 How much time is needed for a constructed wetland to become fully operational and meet discharge requirements?

Several growing seasons may be needed to obtain the optimal vegetative density necessary for treatment processes. The length of this period is somewhat dependent on the original planting density and the season of the initial planting. Effluent quality has been observed to improve with time, suggesting that vegetation density and accumulated plant litter play an important role in treatment of wastewater.

The time required for subsurface flow wetland systems to become fully operational is considerably less than surface flow systems because of the smaller role of plants in the treatment process.

2 How long does it take for the plants to fully establish themselves?

How long it takes for a constructed wetland to function well depends on how fast the recommended wetland plants take root and start growing. Conditions must be suitable for these plants such as the soil type, water level, exposure to sunlight etc. Once the plants have established themselves they can play their role in the treatment of wastewater. In our project at NAHRIM, the wetland plants were fully established in 4 months. In other project areas this process normally took about 6 months.

3 How long can a Surface Flow Wetland operate before accumulated plant material and settled soils need to be removed?

Surface Flow Wetland systems receiving oxidation pond effluent may operate for 10 to 15 years without the need to remove accumulated litter and settled nondegradable influent solids. However, further studies will reveal that there is a limited period of accumulation that will result in the need to remove solids. In both types of systems, the bulk of the solids accumulation will occur at the influent end of the system. As a result, solids may need to be removed from only a portion of the system, that may be as small as 10 to 25% of the surface area.

4 How much effort is required to operate and maintain a constructed wetland?

These systems require minimum maintenance effort. Monthly or weekly inspection of weirs and weekly sampling typically are required at the effluent end and periodic sampling between multiple wetland cells is recommended.

Sediment accumulation typically is not a problem in a well-designed and properly operated constructed wetland, thus partial dredging is rarely required.

Manual labour is required to harvest unwanted plants or overgrowth of plants, control of pests, especially mosquitoes by using integrated pest management practices and for clearing of blockages or sediments when required. Harvesting of plants generally is not required, but annual removal or thinning of vegetation or replanting of vegetation may be needed to maintain flow patterns and treatment functions.

These tasks would require approximately one day per week of labour for a wetland system treating a flow of 3,880 m^3/d (one million gallons per day) or less and monitoring may be the most demanding task.

5 Do constructed wetlands produce odours?

Constructed wetlands incorporate normal processes of decomposition over a relatively large area, thus diluting odours associated with the natural decomposition of plant material, algae and other biological solids. However, wetland treatment systems receiving septic tank and primary effluents can release anaerobic odours around the inlet piping, which makes odour generation a major operational concern.

6 Are mosquitoes a potential problem with constructed wetlands?

Mosquitoes generally are not a problem in properly designed and operated Subsurface Flow Wetland systems. However, mosquitoes can be a problem in a Surface Flow Wetland system. If a Surface Flow System wetland is designed with sufficient open water (40 to 60% of the surface area) to allow effective control with mosquito eating fish, and inlet and outlet weirs are placed as to allow water level control and drainage of wetland cells, the potential for mosquito populations to thrive is reduced. This latter concept provides for isolation of various wetland cells to allow them to be drained and/or to allow predators and mosquitoes to become concentrated in pools and channels. Along with these physical factors, the development of a balanced ecosystem that includes other aquatic invertebrates (beetles), aquatic insects (dragonflies and damselflies), fish (lampan, gobies and others), birds (swallows, ducks, and others) and mammals (bats) will help maintain acceptable levels of mosquitoes. Under these conditions, the mosquito is simply a component in a balanced food web.

If an imbalance develops, then intervention with certain biological and chemical agents may be required.

7 What is the present level of application of this technology?

The use of constructed wetlands started in Malaysia in 1999 with the creation of Putrajaya Wetlands. Putrajaya Wetlands covers about 200 hectares and is believed to be one of the largest constructed freshwater wetlands in the tropics. Putrajaya Wetlands is considered a pioneer venture in constructed wetland treatment systems in Malaysia. It is an excellent example of a water management system in an urban setting.

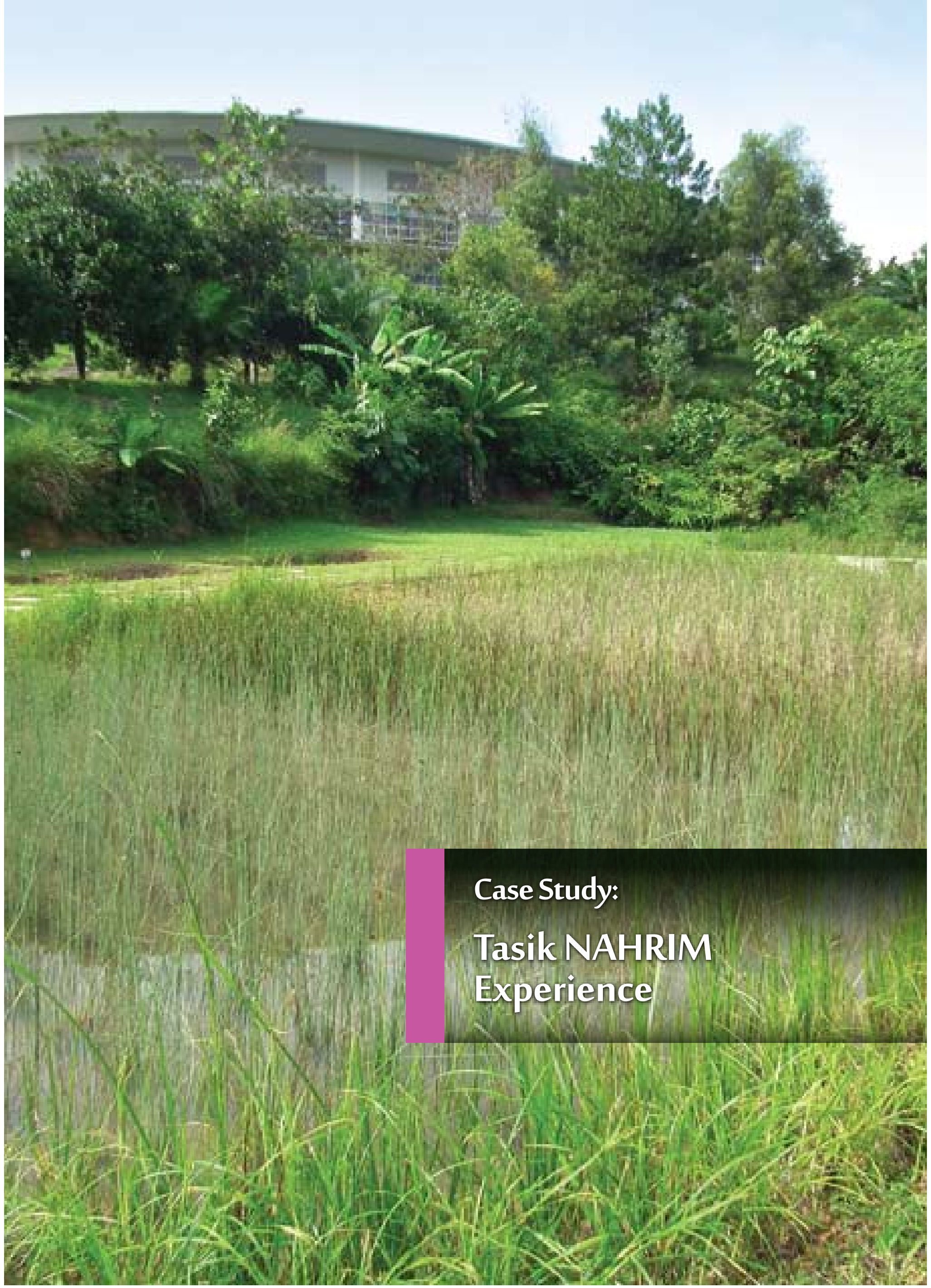
In 2002, a housing developer approached Wetlands International Malaysia for technical advice and assistance to set up Kota Kemuning Wetlands to provide a solution for drainage problems occurring in this low lying residential area. Following the success of the Putrajaya wetlands, the Public Utilities Board of Singapore contacted Wetlands International, Malaysia for assistance in setting up a pilot study to determine the efficiency of a constructed surface flow wetland system in treating surface runoff and other pollutant sources from the monsoon drain.

In 2005 and 2008 respectively, two well known golf courses in Kuala Lumpur converted a few lakes in their vicinity into constructed wetlands to make their golf courses more aesthetically appealing and to improve the water quality in the lakes. The flowering plants and wildlife attracted to the area by the wetlands increase the beauty of the golf courses. Early 2012, NAHRIM and Wetlands International, Malaysia worked together to convert an unused lake into a constructed wetland to treat wastewater. During this period, a few well known developers also enquired about using constructed wetlands to treat wastewater and stormwater runoff, to act as retention ponds for excess rainwater and also to increase the value of the property they are developing.

The concept of constructed wetlands is still relatively new but it is gaining popularity in Malaysia.

8 Can you receive full treatment benefits from a constructed wetland that also provides ancillary benefits such as wildlife habitat?

Multiple benefits can be obtained from a constructed wetland if it is properly sited and designed. For example Surface Flow Systems, wetlands that have a significant portion of surface area occupied by submergent wetland plants and deeper water have been found to produce good quality effluent which gives it greater habitat value. It becomes a suitable breeding ground for fish, birds and others. It can also become a suitable feeding ground for waterbirds and small mammals that visit these areas to feed. It can act as a source of fresh water.



Case Study:

Tasik NAHRIM Experience

NAHRIM recently developed a constructed wetland in their research institute compound for educational and research purposes, with technical advice and assistance from Wetlands International, Malaysia.

There were 3 small wetland cells and a main lake in the Institute's compound that were silted up and overgrown with grass and invasive wetland plants. NAHRIM decided to rehabilitate the area and after some research decided to convert the lake into a constructed wetland to treat wastewater from surface runoff and storm drains discharge before being discharged into the main lake.

The main objectives for the constructed wetland were:

1. To improve and maintain the water quality of Tasik NAHRIM to class IIB based on Malaysia Water Quality Standard which means suitable for recreational use with body contact.
2. To serve as a pollutant control medium by sediment trapping and filtration, retaining excess nutrients and other pollutants.
3. To conserve and improve the richness of the aquatic biodiversity of the lake environment, by increasing the abundance of species to reflect a healthy lake environment.

Design and modification of the wetland cells

1. A wetland cell was deepened to the depth of one meter to serve as a forebay or reservoir for water retention, and to slow down surface runoffs and wastewater flow from the storm drains before the water enters into the wetland cells. Two wetland cells were merged to form a bigger wetland cell which was then enlarged to increase the wetland planting area. The wetland cell was designed with a gentle slope measuring 15 – 30cm from the forebay towards the main lake. This was done to create an ideal condition for the establishment of wetland plants.

2. Two embankments/berms were constructed; one between the forebay and the wetland cell, and the other one across the wetland cells bordering the main lake. The gate of the embankment was designed for easy operation to control the water level.
3. The slope surrounding the wetland cell was designed with two levels to enable planting of marsh wetland plants and shallow marsh wetland plants.
4. The existing three small ponds next to the wetland cell were deepened to different depths of 45cm, 60cm and 90cm respectively for future research purposes.

Types of plants used for the constructed wetlands at NAHRIM

The wetland cell is made up of three wetland zones to create suitable conditions for the wetland plants. Wetland plants are most commonly classified by their zonal position in the natural habitat. The wetland zones consist of a deep marsh zone (> 0.3m water depth), a marsh zone (0.3 – 0.1m water depth) and a shallow marsh zone (0 to 0.1m depth).

In total 12 species of wetland plants species have been planted in the different wetland zones namely:

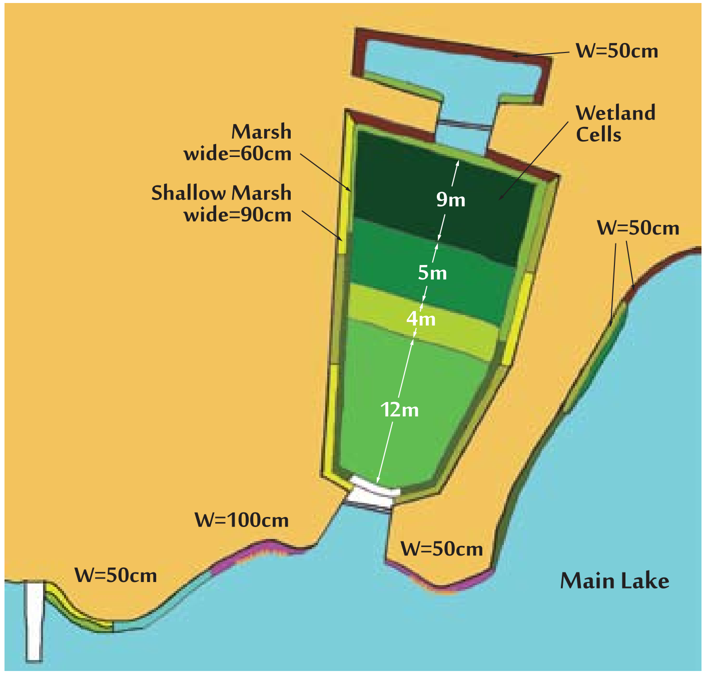
i) Deep marsh zone (>0.3 m water depth):
   a) *Lepironia articulata* (Purun),
   b) *Typha angustifolia* (Banat),
   c) *Phragmites karka* (Rumput gedabong);

ii) Marsh zone (0.1 m – 0.3 m water depth):
   a) *Scirpus mucronatus* (Rumput kercut),
   b) *Eleocharis dulcis* (Ubi puron),
   c) *Scripus grossus* (Rumput menderong);

iii) Shallow marsh zone (0 to 0.1 m depth):
   a) *Eleocharis variegate* (Puron),
   b) *Rhynchospora corymbosa* (Rumput sendayan),
   c) *Scleria sumantrensis* (Rumput kumba);

iv) Specific area in main lake:
   a) *Hanguana malayana* (Bakong),
   b) *Ludwigia octovalvis* (Naleh) and
   c) *Polygonum barbatum* (Panji-panji)

Tasik NAHRIM Wetland Rehabilitation - Wetland Plants Planting Maps



Planting Density: **12 plants per m^2**

Legend - Wetland Plants

Deep Marsh Plants

- Lepironia articulata (Purun; Tube sedge)
- Typha angustifolia (Bahat, lembang; cat-tail)
- Phragmites karka (Rumput gedabong; common reed)

Shallow Marsh Plants

- Eleocharis variegata (Puron; spike rush)
- Rhynchospora corymbosa (Rumput sendayan; golden beak sedge)
- Scleria sumantrensis (Rumput kumba; Sumatran scleria)

Marsh Plants

- Scirpus mucronatus (Rumput kercut; bog bulrush)
- Eleocharis dulcis (Ubin puron; spike rush)
- Scirpus grossus (Rumput menderong; great club rush)

Spot Planting

- Hanguana malayana (Bakong; common hanguana)
- Ludwigia octovalvis (Inai pasir; water primrose)
- Polygonum barbatum (Panji-panji; knot grass)

What has been achieved?

The constructed wetland is now fully functional. All the wetland plants have taken root and are performing their roles in treating wastewater. This constructed wetland was also set up to carry out research on the effectiveness of wetland plants pollutant removal. The wetland not only assists to remove pollutants naturally from the lake system, but it also aesthetically enhances the surroundings of NAHRIM. The wetland area has attracted many species of dragonflies to the lake. It has also increased the number of bird species which are found within NAHRIM's vicinity.

Condition of project site before conversion to constructed wetland. There were 3 small wetland cells which were silted up and overgrown with grass and invasive wetland plants.

Project site after conversion to constructed wetland with well established wetland plants.

Glossary

Algae are single-celled to multicelled organisms that rely on photosynthesis for growth. Most algae are classified as plants.

Anaerobic processes in wastewater treatment systems take place in the absence of dissolved oxygen and instead rely on molecular oxygen available in decomposing compounds.

Atmospheric reaeration introduces atmospheric oxygen into the water at the water's surface, which provides dissolved oxygen to the aquatic environment.

Biochemical oxygen demand (BOD) is the demand for dissolved oxygen that decomposition of organic matter places on a wastewater treatment process.

Constructed wetlands are wastewater treatment systems that rely on physical, chemical, and biological processes typically found in natural wetlands to treat a relatively constant flow of pretreated wastewater.

Indigenous species are species of plants that are native to an area.

Microorganisms are microscopic organisms (only viewed with a microscope), such as bacteria, protozoans, and certain species of algae, which are responsible for many of the biochemical transformations necessary in wastewater treatment processes.

Phytoplankton are algae that are microscopic in size which float or drift in the upper layer of the water column and depend on photosynthesis and the presence of phosphorus and nitrogen in the water.

Rhizomes Root-like stem that produces roots and stems to propagate itself in a surrounding zone.

Total suspended solids (TSS) are particulate matter in wastewater consisting of organic and inorganic matter that is suspended in the water column.

Wastewater treatment is the process of improving the quality of wastewater. The term can refer to any part or parts of the process by which raw wastewater is transformed through biological, biochemical, and physical means to reduce contaminate concentrations to prescribed levels prior to release to the environment.

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