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Chapter 19

Operation and Maintenance for Constructed Wetlands

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Abstract. Correct operation and maintenance will ensure that constructed wetlands operate as designed and that the objectives are achieved over the life of the system. There are definitive stages in the life of a constructed wetland where management options differ. These include: planning; commissioning; operation; and decommission/retrofitting. This chapter will highlight the importance of operation and maintenance planning. The suggested structure is based on the knowledge gained from the implementation and operation of many wetland systems across Australia. Although management activities required for the operation and maintenance of constructed wetlands within South-East Asia may differ slightly, the structure suggested is relevant for all constructed wetlands, regardless of the location.

Some important management issues of surface wetlands are also addressed including: management of sediment and gross pollutants; plant management; mosquito management; and algal management.

19.1. Introduction

The challenges associated with the successful utilisation of constructed wetlands do not end with design and construction, but go beyond to their subsequent maintenance and operation. Properly managed, constructed wetlands are "passive" and low-maintenance systems. However, they are by no means no-maintenance systems. Constructed wetlands are complex and dynamic with many variables that require managing. Problems will occur when:

- wetlands are poorly designed and constructed;
- the operator has an inadequate understanding of the system;
- the wetland is overloaded, both in terms of hydraulic overload and pollutant overload (White, 1995);

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- natural disasters occur;
- the wetland is plagued by weed problems; and
- excessive amounts of sediment and litter accumulate and are not removed from the system.

19.2. The Phases of Wetland Operation and Maintenance

The operation and maintenance of a wetland can be divided into four distinct phases: planning and construction; commissioning; operation; and decommissioning or major refitting (Beharrell et al., 1996).

19.2.1. Planning and Construction

During the design process many operation and maintenance issues must be considered. Access to all points of the wetland must be provided for operation and maintenance activities. Pretreatment should be provided to formalise areas of sediment deposition and removal of gross pollutants. These must be designed for ease of maintenance. Most importantly water level control must be available.

Poor design, for example, inadequate sizing, will lead to reduced performance and increased levels of operation and maintenance. If the design is inadequate in terms of pollutant removal, overloading will occur and retrofitting or increased pretreatment will be required to maintain the wetland viability.

Currently in Australia many treatment wetlands are constructed by Local Authorities with grant monies from State Authorities. In urban situations wetlands are frequently undersized to fit into the existing environment. A perception exists that something is better than nothing (Seymour, 2000). Generally, these wetlands fail to meet their objectives, have mosquito problems and become maintenance burdens.

A major constraint to surface water wetlands for treatment or habitat can arise from the presence of noxious weeds in vicinity. Weed propagules tend to get carried into wetlands where they can thrive, diminishing visual amenity and wetland function. The presence of certain aggressive weed species may even lead to a constructed wetland being unfeasible.

As with all civil works, attention to detail during construction is required. Failure at this stage will result in on-going maintenance and/or repairs.

19.2.2. Commissioning

This phase will encompass the time from planning to the date at which the wetland is considered operational. During this period, management activities should be tailored to ensure an adequate cover of wetland vegetation. Other specific activities should include:

- "debugging", where minor problems are recognised and resolved, for example structural problems affecting stability of structures in the future — for example rill erosion;
- careful control of water levels to prevent desiccation or inundation of seedlings. Once plants have established, water levels can then be raised to operational levels;
- supplementary planting to fill in gaps; and
- control of weed species which is simpler when infestations are small, surface water wetlands are prone to invasion when the desired vegetation is not well established.

Generally, this period will coincide with plant establishment. Inspections should be frequent and undertaken on a weekly basis, with maintenance being continual.

19.2.3. Operation

The operational phase of the wetland will encompass the active life of the wetland. During this phase the design objectives should be met. Successful maintenance and operation during this phase will prolong the lifespan of the wetland, delaying the need for decommissioning and/or refitting (Beharrell et al., 1998).

19.2.4. Decommissioning or Refitting

At some stage a constructed wetland will either be refitted or decommissioned (White & Kuginis, 1995). For example refitting or decommissioning may be required when accretion of wetland sediments is adversely affecting wetland performance. It is essential that, during this phase, priority be given to public safety. The impact on mosquito production, structural failure and the removal and disposal of possibly toxic sediments should therefore be examined.

19.3. Operation and Maintenance Plans

Operation and maintenance plans are important for the following reasons (Beharrell et al., 2001):

1. they provide direction for the system to be operated as designed and maintenance undertaken to meet the wetland objectives;

2. they save money — early detection of problems will often result in solutions that are much cheaper and simpler to solve than later remedial action. For example controlling weed infestations at an early stage when only sections rather than the entire wetland is affected;
3. changes in personnel can be catered for and loss of corporate knowledge reduced.

An operation and maintenance plan provides the framework for management within which an operator can make decisions based on monitoring, observation, advise and experience. If operation and maintenance of a constructed wetland is to be effective, some party (for example, State or Local authority, private landholder, etc.) who will take on the responsibility for its management must own it.

19.3.1. General Considerations in an Operation and Maintenance Plan

An adaptive approach to the operation and maintenance of constructed wetlands is recommended (White, 1995). Operation and maintenance plans should therefore be flexible and not constitute a full set of instructions or "recipe". Such management plans should be easily understood and considered by the operators as a living document, which can be modified and adapted to the changing needs of the wetland and to information obtained through monitoring and experience (Beharrell et al., 1996).

The operator's understanding/knowledge of the components and processes occurring within the wetland is crucial for informed and effective management. The operator needs to be aware that constructed wetlands do not operate in isolation: its "health" is an expression of the activities occurring within its catchment. The wetland itself can affect the downstream catchment, either through surface water or groundwater, if connected to the wetland.

Not all constructed wetlands share the same goals. They can be designed to satisfy any number of objectives, from water quality improvement, habitat enhancement and/or creation, to aesthetic and educational values. For example wetlands for habitat may require vegetation control to provide roosting and nesting sites for specific wading birds.

The function or objective for which a wetland is designed will determine the kind of management activity undertaken. Management activities will also be influenced by the nature of flow (stormwater, sewage or industrial effluent) entering the wetland (Kuginis, 1998).

Site-specific constraints will affect wetland operation and maintenance. Site-specific constraints include: climate; the presence and/or lack of groundwater; the location; and type (freshwater/estuarine or stormwater) of surface water.

For example, a wetland situated in arid to semi-arid regions may be ephemeral, whilst in other environments, rainfall may exceed evaporation, creating a “perennial” wetland.

There are numerous types of constructed wetlands including surface water wetlands, subsurface wetlands, natural treatment wetlands (Kadlec & Knight, 1996a). These will all have their own particular issues, for example clogging of substrates in subsurface wetlands.

19.3.2. What Does an Operation and Maintenance Plan Need to Contain?

In brief, the essential elements of an operation and maintenance plans are:

- a description of the constructed wetland and its objectives;
- a description of tasks and/or management activities;
- a management calendar indicating when activities are to be undertaken;
- monitoring activities which include maintenance inspection checklists;
- information on overcoming problems that are unique to that particular wetland. For example, control of a particular weed species, ensuring the health and safety of public, etc.

Management Activities. Management activities are those actions, which are required to operate and maintain a constructed wetland, and ensure that a wetland achieves its desired objectives. A management activity sheet can be used to detail the required tasks. It is important that when preparing these activity sheets that the operator outlines for each management activity the following:

- the management zone in which it is to occur (sedimentation, vegetated or open water zone);
- the technique required — what to do;
- the specifications — how to do it;
- the precautions — what not to do.

Management Calendar. Such calendars can be used to timetable works and ensure that maintenance programmes are ongoing, and that staff and/or funds are available. These calendars can be updated and modified as the experience of the operator increases.

Inspection Checklists. Inspections form an important part of monitoring a constructed wetland to ensure continued efficient operation. They should be conducted at regular intervals and after significant events. These include: heavy rainfall; floods; fire; chemical spills and/or events which can adversely impact the wetland. Inspections should be conducted with the aid of a checklist to provide a list of management activities to be undertaken. These checklists provide a permanent record of maintenance activities, which will aid the owner/operator to demonstrate that quality assurance procedures have been undertaken whilst implementing the plan.

19.3.3. Monitoring

Monitoring is required to assess wetland performance, and is therefore an essential part of an operation and maintenance plan. The information collected will need to be interpreted and applied to upgrade operation and maintenance of the wetland (White & Kuginis, 1995).

Monitoring can be undertaken for maintenance, operational control, research activities and compliance with regulatory requirements. The monitoring program(s) will need to be carefully designed so that the most appropriate information is collected (Beharrell et al., 1998). Aspects of the wetland that can be monitored include:

- Wetland components, including operational structures, aquatic plants and pond embankments. These can be monitored for physical changes, e.g. weed invasion, loss of plants and bank erosion. Monitoring can be undertaken through inspections and with the aid of checklists.
- Various performance indicators to aid in wetland operation and to assist in assessing wetland performance. This will define the need for changes in wetland operation and maintenance, and if necessary, the need for refitting the wetland.
- A range of parameters which can be monitored to research aspects of wetland function and performance. In this instance, the design of the monitoring program will be more rigorous to satisfy research procedures where clear research objectives are defined. Research can provide better design criteria for future wetlands and information for wetland modification to improve performance.

19.3.4. Evaluation of Operation and Maintenance Plans

Evaluation of operation and maintenance plans must be carried out after the first year and then every two years. This should be in conjunction with an outside specialist who has expertise in constructed wetlands and will be able advise on ways in which to increase performance and lower maintenance costs. However, for evaluation to be effective the operator will need to document the successes and problems associated with the operation of the wetland, so to provide insight and lessons for improving management.

19.4. Operation of Wetlands

There are relatively few operational variables that can be managed which affect wetland performance. Generally, the only operational variables that can be managed are water level and flow rate.

19.4.1. Water Level Control

Water level management is frequently the only operational variable that can be utilised to influence wetland performance. Water level control can effect residence time, atmospheric oxygen diffusion, plant diversity and plant coverage.

During the summer period or dry season when water levels would naturally be at their lowest, water temperature is usually elevated and plant productivity the highest. Water levels may need to be artificially lowered to encourage regrowth. Reducing water levels can promote better oxygen diffusion to the wetland sediments and plant roots, as the dissolved oxygen levels are low in warmer waters (Kadlec & Knight, 1996b).

19.4.2. Flow Rates

In municipal or industrial waste situations flow rates to the wetland may be regulated. Flow rates can also be controlled by pretreatment, wetland cells in parallel, and recirculation. The regulation of flow rates can affect hydraulic and pollutant loadings. If performance drops or loadings increase flow rates can be reduced to improve performance.

19.5. Management Issues

There are numerous maintenance issues that require management within constructed wetlands. Many of these will be wetland specific and dependent on wetland objectives, design, type of inflows and the catchment characteristics. It must be remembered that there are some situations where inappropriate design and defective construction will require a significant repair or a retrofit.

The operator may be faced with implementing several maintenance activities at once with limited resources. In this case, the activities will need to be prioritised and a decision made on the allocation of resources.

The order of these priorities should be set with reference to the following issues:

- safety — the safety of the public is of the highest priority;
- stability — a failed structure may cause complete failure of the wetland and it is generally cheaper to maintain/repair than to replace;

- plants — deterioration in health or loss of plants increases the risk of not meeting all objectives; and
- all other management activities — essential for the effective long-term performance of the wetland.

Below are the management issues frequently encountered by the author:

- management of sediment;
- litter management;
- vegetation management;
- algal management;
- mosquito management.

19.5.1. Management of Sediment

Pretreatment of inflows is required for the removal of sediment. To ensure that the hydraulic condition of the wetland and vegetation are maintained, removal of built-up sediment will be required. A stormwater wetland with a developing urban catchment will require more regular sediment removal than a wastewater treatment wetland. When removing sediments from a constructed wetland, ensure that sediment is treated as contaminated fill.

Long-term accumulation of heavy metals or unmodified toxic compounds in wetland sediments and vegetation may result in a reduction of these substances downstream. However, the concentrated deposits of toxins may lead to bioaccumulation in the ecosystem of the wetland. Wetland food chains may then redistribute these toxins, endangering fauna and possibly human health (Kuginis, 1998). This may be of particular concern in wetlands for mine drainage.

19.5.2. Litter Management

A gross pollutant trap (GPT) or litter screen will trap significant amounts of the litter entering stormwater wetlands. GPT design must incorporate access for cleaning and maintenance. Periodic cleaning of the GPT will be required as breakdown products from the decomposing litter may re-enter the water column within 10 days of entrapment (Riley, 1995). Consequently, litter removal should be undertaken within 10 days of storm events.

Debris may also accumulate throughout the wetland, especially if there is no GPT. If optimum performance is to be maintained, the litter and debris needs to be removed periodically and immediately after storm events. Fouled areas will have a reduced performance owing to increased hydraulic pressure on the macrophytes and flattening of the plants. Litter removal will also enhance the wildlife habitat and scenic amenity within the wetland environs.

19.5.3. Vegetation Management

Operation and maintenance of a constructed wetland should aim to sustain the presence of desirable wetland plants. Operators should expect gradual changes in wetland vegetation, a result of some species out-competing less aggressive neighbouring species, and recruitment from the catchment. Species diversity may decline in the long term and it is not usually recommended that any action be taken.

In addition constructed wetlands, like natural ones, undergo species composition changes resulting from natural and artificial disturbance. One or a few species may have become dominant: because they arise from disturbed situations constructed wetlands undergo rapid successional changes after establishment.

Water level control, and separation of individual cells can make it possible to maintain plant diversity. Water level control is extremely important, the majority of wetland species will benefit form period of reduced water levels. If water depths are maintained at a constant level the viability of many wetland species will be affected. Logically these should occur in the dry season. However, if plant health is affected, water level reduction may aid in their recovery. Unfortunately, reduced water level can be at odds with the hydraulic design of the system and habitat requirements.

Weed Management. Due to their location in the catchment and the often nutrient rich nature of inflows, surface treatment wetlands and habitat wetlands allow aquatic weeds to flourish (Beharrell, 1999). Within constructed wetlands weeds should be considered as plants that interfere with the objectives of the wetland (Sainty & Beharrell, 1998). For example, mats of floating noxious weeds have the potential to damage structures and affect water quality through the prevention of oxygenation of the water column leading to water quality problems.

The methods used to control weeds will depend upon the species and size of the infestation. The use of herbicides may affect desired vegetation, and manual removal costs may be excessive. Early recognition and control are the most effective measures. Therefore, wetland operators should be familiar with the identification of all species planted in the wetland and aquatic weed species that occur in the general area and/or catchment.

Once present, control of infestations will usually require integrated weed management involving several control methods. Options for control include:

- herbicide application; there are several selective herbicides which can be utilised in wetlands depending on the target species;
- manual removal;
- mechanical removal;
- water level manipulation; and
- biological controls.

Pest Management. There are many potential pest species which can have impact on vegetation within the wetland Aphids and stem borer have been known to attack various plants such as *Phragmite karka* and *Scirpus grossus*, respectively within wetlands in Malaysia. In most cases of insect attack minimum action was taken as predator numbers increased to control the problem. However, if problems persist treatment with appropriate pesticides may be required: this can affect both the desirable biota and the water quality.

Waterfowl are a potential problem at all stages of a wetland's life. Waterfowl damaging plants and defecation of large groups in small areas can affect water quality. In the commissioning phase they can be particularly troublesome decimating seedlings. Using mature plantings may reduce loss to grazing. Alternatively, consider netting the site or avoid the use of sensitive species. Waterfowl do not usually graze some species, such as *Scirpus mucronatas*. In Australia relocation of waterfowl during plant establishment has been used.

Plant Harvesting. Generally, wetland plant harvesting is not undertaken in treatment wetlands as a method of pollutant removal, as it tends to have limited value (Kadlec & Knight, 1996b). Plant take up rates of pollutants is not the major pollutant removal mechanism within wetlands. The disadvantages of macrophyte harvesting include (DLWC, 1995):

- nutrient and sediment re-suspension from disturbance;
- reduction in habitat values; and
- high cost involved.

However, harvesting may be desirable to address other objectives. Thinning of the vegetation and removal of dead material may be required for mosquito control and to improve wetland aesthetics and hydraulics. Harvesting would also occur when a major refit of the wetland is required.

19.5.4. Mosquito Management

Surface water constructed wetlands provide habitat for mosquitoes. Mosquito biology and ecology vary with species, and different species can occupy different niches within a single wetland (Russell, 2000). If there is a perceived mosquito risk, monitoring via larval surveys and strategic population sampling is necessary to determine prevalence and species.

Whilst the initial design plays a major role in reducing mosquito populations, there are some water management techniques that can be utilised to manage populations (Russel & Kuginis, 1998). Techniques include:

- sprinkler or aeration systems that disrupt the water surface;
- water level fluctuations which can be used to control some species, but may increase problems with others (Russell & Kuginis, 1995); and
- periodic draining of the wetlands.

Plant management can also be practised to control mosquitoes. Vegetation can be thinned to allow better access for predators. Floating vegetation and algal mats should be removed which harbour same species. However, as a last resort population can be controlled by chemical and biological larvicides.

19.5.5. Algal Growth

Most surface water wetlands will have blooms of algae at some time because they frequently have ideal conditions for algal growth. These include high nutrient concentrations, shallow water providing idea water temperatures, low velocities, and high hydraulic retention times (Bowling, 1998). Generally, filamentous green algal will be present, occasionally there maybe blooms of Cyanobacteria.

Treatment wetlands frequently have significant algal blooms when first completed. Generally, these subside over time as the system stabilises, and shading from the growing wetland vegetation develops. However, algal growth can have a serious impact on visual amenity in surface water constructed wetlands. Large mats of algae can smother plants and rapidly release accumulated nutrients during decomposition (Sainty & Dalby-Ball, 2000) affecting wetland performance. Decomposing algae can frequently lead to excessive odours.

Generally, the impact on the performance of the system due to the algae is minimal, with treatment only taking place when the wetland objectives are compromised. To minimise algal growth there are several maintenance options available these include:

- Water movement, reducing the water column stability can reduce the incidence of algal growth. Velocity of flows can be increased in systems where this is possible or sprinkler systems can be installed. However, flows should remain relatively low to avoid impacts on wetland physiochemical processes.

- The applications of algicides are frequently used to treat algal problems. These treatments lead to water quality problems and should only be considered as a final measure.
- Shading in shallow areas can be very effective in reducing algal growth. However, the open water areas remain problematic.
- Nutrient removal can impact on algal growth. However, the ability to increase nutrient removal within the system is usually limited. Increase pretreatment of flows maybe considered. There are also several products in the market that can readily reduce the level of nutrients within a wetland in the short-term. For example Phoslock® and Barley Straw.
- Removal of the algae from the open water area can be readily undertaken manually or by machine. This can be incorporated into regular maintenance of the system or as one-off treatments.

19.6. Conclusion

Operation and maintenance activities will change during the lifetime of a constructed wetland. Ultimately the wetland may become inefficient or redundant leading to the site being decommissioned or retrofitted.

To extend the life of constructed wetlands, operation and maintenance must be planned. To facilitate this, an operation and maintenance plan should be developed. This plan must be specific to the wetland and easy to use. In short, the plan should state what is to be done, when it is to be done and how it is to be done.

Monitoring must be undertaken to ensure that wetland objectives are being met and to further define the type and level of maintenance required. Wetland operation and maintenance is more than just cleaning structures. Wetland operation and maintenance relies on attention to detail and an understanding of the functions and processes within the system.

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