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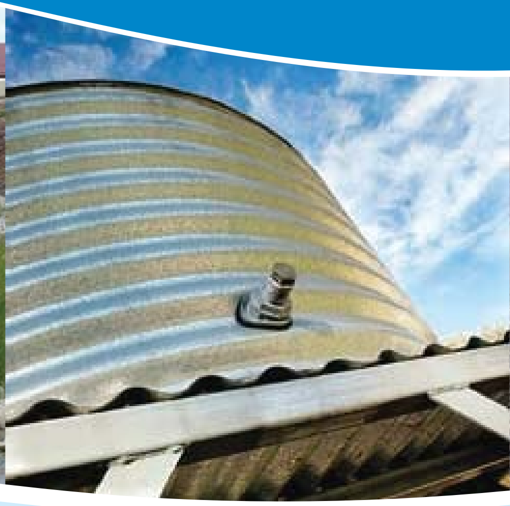
Chapter 13

Constructed Wetlands

Water Sensitive Urban Design Technical Manual
Greater Adelaide Region

Government of South Australia

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Department of the Environment, Water, Heritage and the Arts

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Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the urban development process. It includes:

- Integrated management of groundwater, surface runoff (including stormwater), drinking water and wastewater to protect water related environmental, recreational and cultural values;
- Storage, treatment and beneficial use of runoff;
- Treatment and reuse of wastewater;
- Using vegetation for treatment purposes, water efficient landscaping and enhancing biodiversity; and
- Utilising water saving measures within and outside domestic, commercial, industrial and institutional premises to minimise requirements for drinking and non drinking water supplies.

Therefore, WSUD incorporates all water resources, including surface water, groundwater, urban and roof runoff and wastewater.

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The project partners gratefully acknowledge all persons and organisations that provided comments, suggestions and photographic material.

In particular, it is acknowledged that material was sourced and adapted from existing documents locally and interstate.

Overall Project Management

Christine Lloyd (Department of Planning and Local Government)

Steering Committee

A group of local government, industry and agency representatives provided input and feedback during preparation of the Technical Manual. This group included representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- Australian Water Association (AWA);
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Water, Land and Biodiversity Conservation (DWLBC);
- Environment Protection Authority (EPA);
- Housing Industry Association (HIA);
- Local Government Association (LGA);
- Department of Planning and Local Government (DPLG);
- South Australian Murray-Darling Basin Natural Resources Management Board;
- South Australian Water Corporation;
- Stormwater Industry Association (SIA); and
- Urban Development Institute of Australia (UDIA).

Technical Sub Committee

A technical sub committee, chaired by Dr David Kemp (DTEI), reviewed the technical and scientific aspects of the Technical Manual during development. This group included representatives from:

- Adelaide and Mt Lofty Ranges Natural Resources Management Board;
- City of Salisbury;
- Department for Transport, Energy and Infrastructure (DTEI);
- Department of Health;
- Department of Water, Land and Biodiversity Conservation;
- Department of Planning and Local Government; and
- Urban Development Institute of Australia.

From July 2010, DWLBC was disbanded and its responsibilities allocated to the newly created Department For Water (DFW) and the Department of Environment and Natural Resources (DENR).

Specialist consultant team

Dr Kylie Hyde (Australian Water Environments) was the project manager for a consultant team engaged for its specialist expertise and experience in water resources management, to prepare the Technical Manual.

This team comprised Australian Water Environments, the University of South Australia, Wayne Phillips and Associates and QED Pty Ltd.

Beecham and Associates prepared Chapter 16 of the Technical Manual.

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13.1 Overview

As detailed in **Chapter 1**, there are many different WSUD measures which together form a 'tool kit' from which individual measures can be selected as part of a specific design response suiting the characteristics of any development (or redevelopment). Constructed wetlands are one of those measures.

This chapter of the Technical Manual for the Greater Adelaide Region is aimed at providing a general overview of the benefits of constructed wetlands and how they can be utilised to achieve water quality and water quantity objectives and targets.

Further detailed design information can be obtained from the references included in the Useful Resources and Further Information section (see **Section 13.11**).

Description

Wetlands are complex, natural, shallow water environments that are dominated by hydrophytic (water loving) vegetation. This distinguishes them from deep water habitats that are dominated by large areas of open water.

Constructed wetlands are designed to utilise the benefits of natural wetland functions and processes for various purposes.

They are shallow, extensively vegetated water bodies that use enhanced sedimentation, fine filtration and biological uptake processes to remove pollutants from runoff.

In addition to treating water, constructed wetlands can also provide habitat, passive recreation, improved landscape amenity and temporary storage of treated water for reuse schemes.

Wetlands generally consist of:

- An inlet zone (sedimentation basin to remove coarse sediments (refer **Chapter 12 -** Sedimentation Basins));
- A macrophyte zone (a shallow heavily 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).

Figure 13.1 shows the key elements of constructed wetland systems.

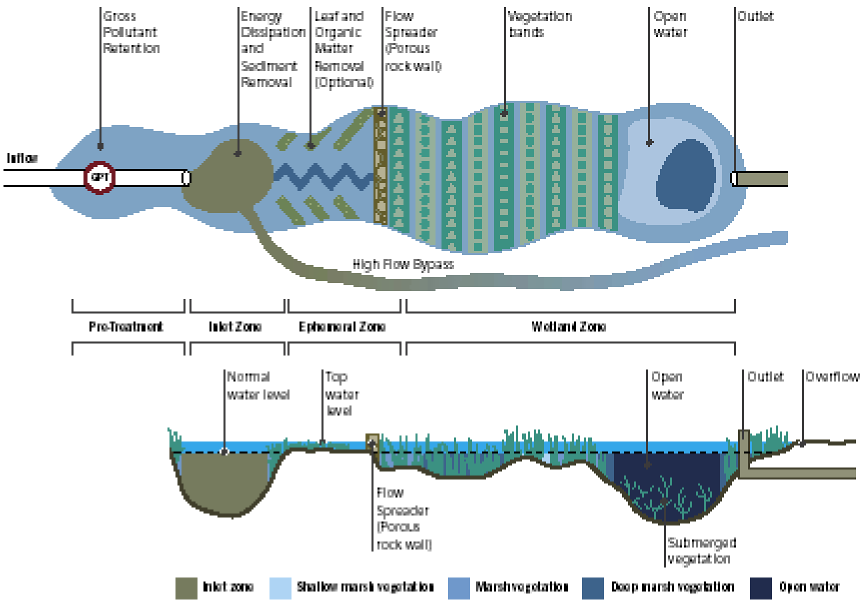

Figure 13.1 Long Section Schematic of a Typical Representation of a Constructed Wetland

Source: Melbourne Water (2005)

Constructed wetlands are particularly useful where runoff contains high concentrations of soluble material that is difficult to remove with other treatment methods.

Depending on their design, constructed wetlands can also serve to attenuate larger storm events, offsetting the changes to flow frequency relationships caused by increased catchment imperviousness. Constructed wetlands also increase flora and fauna habitat in already urbanised catchments where many natural wetlands have been cleared, drained or filled. They also provide passive recreation opportunities and can provide opportunities for educational and scientific studies.

Purpose

Scientific knowledge of the functions and values of wetlands has developed during the past 40 years. Until very recently, the filling and draining of wetlands was accepted practice to 'improve' the land. Wetlands are nature's '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 resource systems.

The five principal purposes of constructed wetlands are:

- To compensate for and help offset the rate of loss of natural wetlands as a result of agriculture and urban development;
- To improve and maintain water quality;
- To provide attenuation of flood flows;
- To provide habitats which support aquatic life and wildlife; and
- To provide recreational amenity.

Multiple use constructed wetlands, which combine a number of purposes and benefits, are becoming more common in urban situations.

Generally, wetlands are designed for water quality control (to treat urban runoff to remove contaminants that would be potentially detrimental to the receiving water ecosystem). However, as for many catchment scale systems, wetlands can have significant flood control potential through the inclusion of specifically designed storage components.

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

Scale and Application

Wetlands are most appropriate on sites that meet or exceed the following criteria (Hobart City Council 2006):

- Catchment area more than approximately 1 hectare;
- Soils that are silty through clay;
- No steep slopes or slope stability issues; and
- No significant space limitations.

Constructed wetlands should only be used in areas that have enough inflow from rain, upstream runoff, treated wastewater or groundwater inflow to ensure the long-term viability of wetland processes.

Constructed wetlands are most applicable on the street scale and precinct or catchment/regional scale.

Figure 13.2 Brookes Bridge Wetland, Upper Cox Creek, Adelaide Hills

Source: Courtesy of Australian Water Environments

Performance Efficiency

Changes in environmental conditions can greatly influence wetland processes. These include diurnal changes in water temperature and dissolved oxygen, seasonal changes in daylight hours, water temperature, water depth, wetland vegetation growth, microbiological activity and chemical reactions. In areas with significant seasonal variation in water temperature, the treatment efficiency for a particular contaminant may vary markedly at different times of the year.

Indicative estimates for treatment efficiencies of a constructed wetland are provided in **Table 13.1**, however actual treatment efficiencies will depend on the hydraulic efficiency and the design of the wetland.

Table 13.1 Typical Annual Pollutant Load Removal Efficiencies for Constructed Wetlands

Pollutant	Expected Removal	Comments
Litter	> 95 %	Subject to appropriate hydrologic control
Total suspended solids	65-95 %	Depends on particle size distribution
Total nitrogen	40-80%	Depends on speciation and detention time
Total phosphorus	60-85 %	Depends on speciation and particle size distribution
Coarse sediment	> 95%	Subject to appropriate hydrologic control
Heavy metals	55-95%	Quite variable, dependent on particle size distribution, detention time etc

Source: Department of Environment WA (2004)

13.2 Legislative Requirements and Approvals

Before undertaking a concept design of a constructed wetland it is important to check whether there are any planning regulations, building regulations or local health requirements that apply to constructed wetlands in your area. Refer to the suggested design process in **Section 13.5**.

The legislation which is most applicable to the design and installation of constructed wetlands in the Greater Adelaide Region includes:

- *Development Act 1993* and Development Regulations 2008; and
- *Environment Protection Act 1993*.

Development Act 1993

Installation of a constructed wetland will generally be part of a larger development, however whenever a constructed wetland is planned, it is advised that the local council be contacted to:

- Determine whether development approval is required under the *Development Act 1993*; and
- Determine what restrictions (if any) there may be on the installation of constructed wetlands in the area.

Environment Protection Act 1993

Any development, including the construction of wetlands, has the potential for environmental impact, which can result from vegetation removal, stormwater management and construction processes. There is a general environmental duty, as required by Section 25 of the *Environment Protection Act 1993*, to take all reasonable and practical measures to ensure that the activities on the whole site, including during construction, do not pollute the environment in a way which causes or may cause environmental harm.

Aspects of the *Environment Protection Act 1993* which must be considered when considering the design and installation of a constructed wetland are discussed below.

Water Quality

Water quality in South Australia is protected using the *Environment Protection Act 1993* and the associated Environment Protection (Water Quality) Policy 2003. The principal aim of the Water Quality Policy is to achieve the sustainable management of waters by protecting or enhancing water quality while allowing economic and social development.

In particular, the policy seeks to:

- Ensure that pollution from both diffuse and point sources does not reduce water quality; and
- Promote best practice environmental management.

Through inappropriate management practices, construction sites can be major contributors of sediment, suspended solids, concrete wash, building materials and wastes to the stormwater system. Consequently, all precautions will need to be taken on a site to minimise potential for environmental impact during construction. Guidance can be found in the EPA Handbook for Pollution Avoidance on Building Sites (see **Section 13.11**).

Constructed wetlands will assist in improving the water quality that is discharged to receiving waters.

Noise

The issue of noise has the potential to cause nuisance during any construction works of wetlands. The noise level at the nearest sensitive receiver should be at least 5 dB(A) below the Environment Protection (Industrial Noise) Policy 1994 allowable noise level when measured and adjusted in accordance with that policy. Reference should be made to the EPA Information Sheets on Construction Noise and Environmental Noise respectively to assist in complying with this policy (see **Section 13.11**).

Air Quality

Air quality may be affected during the construction of a wetland. Dust generated by machinery and vehicular movement during site works and any open stockpiling of soil or building materials at the site must be managed to ensure that dust generation does not become a nuisance off site.

Waste

Any wastes arising from any excavation and construction work on a site should be stored, handled and disposed of in accordance with the requirements of the *Environment Protection Act 1993*. For example, during construction, all wastes must be contained in a covered waste bin (where possible) or alternatively removed from the site on a daily basis for appropriate off-site disposal. Guidance can be found in the *EPA Handbook for Pollution Avoidance on Building Sites* (see **Section 13.11**).

13.3 Design Considerations

The operation of constructed wetlands involves the interaction between water (runoff or treated wastewater), vegetation and hydraulic structures. The successful implementation of constructed wetlands requires appropriate integration into the landscape design.

Wetland construction should only be considered when environmental and health concerns can be adequately addressed through design and realistic maintenance regimes.

Design considerations for constructed wetlands include:

- Hydrology;
- Water quality;
- Mosquitoes;
- Maintenance;
- Safety;
- Landscape and vegetation; and
- Services.

The following sections provide an overview of the key design issues that must be considered when conceptualising and designing constructed wetlands.

Detention Time and Hydrologic Effectiveness

Detention time is the time taken for each 'parcel' of water entering the wetland to travel through the macrophyte zone assuming 'plug' flow conditions. In highly constrained sites, simulations using computer models are often required to optimise the relationship between wetland detention time and wetland hydrologic effectiveness to maximise treatment performance.

It should be noted that detention time is rarely a constant and the term 'notional detention time' is used to provide a point of reference in modelling and determining the design criteria for riser outlet structures.

Hydrologic effectiveness is a measure of the mean annual volume of water captured and treated within the wetland and is expressed as a percentage of the mean annual runoff volume generated from the contributing catchment (it should be greater than 80% for well designed wetlands).

The relationship between notional detention time and pollutant removal efficiency is largely influenced by the settling velocity of the target particulates. It is recommended that a notional detention time should preferably be 72 hours (and not less than 48 hours) to remove nutrients effectively from urban runoff in the Greater Adelaide Region.

The range of detention times achieved in a constructed wetland is influenced by the type of outlet structure used. The volume of the permanent pool also has a significant effect on the range of detention times achieved as a result of operational conditions. The impact of these design choices needs to be taken into account during the concept design.

Water level control is desirable in wetland design to enable maintenance and to assist with vegetation establishment.

Inlet Zone Design Considerations

The inlet zone of a constructed wetland is designed as a sedimentation basin (see **Chapter 12**) and has two key functional roles. The primary role is to remove coarse to medium sized sediment (i.e. 125 µm or larger) prior to flows entering the macrophyte zone. This ensures the vegetation in the macrophyte zone is not smothered by coarse sediment and allows this zone to target finer particulates, nutrients and other pollutants.

The second role of the inlet zone is the control and regulation of flows entering the macrophyte zone and bypass of flows during 'above design flow' conditions. The outlet structures from the inlet zone (i.e. sedimentation basin) are designed such that flows up to the 'design flow' (typically the 1 year ARI) enter the macrophyte zone whereas 'above design flows' are bypassed around the macrophyte zone. In providing this function, the sedimentation basin protects the vegetation in the macrophyte zone against scour during high flows.

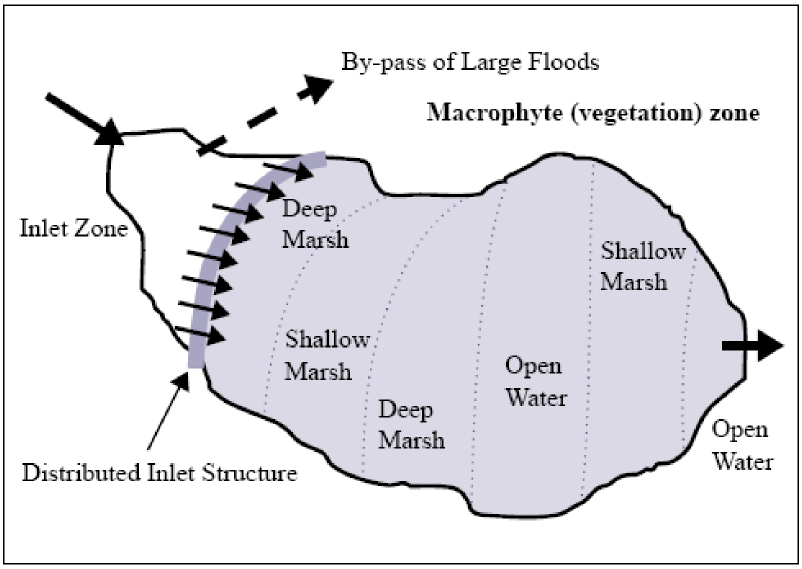

Figure 13.3 Illustration of Typical Constructed Wetland Layout

Source: Wong (1998)

Note that when the available space for a constructed wetland is constrained, it is important to ensure that the size of the inlet zone (i.e. sedimentation basin) is not reduced. This ensures the larger sediments are effectively trapped and prevented from smothering the macrophyte zone. When the site constrains the size of the constructed wetland it is the macrophyte zone of the wetland that should be reduced accordingly.

Large wetland systems usually require a gross pollutant trap (GPT) (see **Chapter 9**) as part of the inlet zone to protect the wetland from litter and debris. Determining whether a GPT is required or not depends on the presence of upstream GPT measures, the catchment size and catchment type.

The inlet zone is also required to remove high organic loads. It should be noted that high organic loads can be problematic for wetland systems.

Macrophyte Zone Design Considerations

The layout of the macrophyte zone needs to be configured such that system hydraulic efficiency is optimised and healthy vegetation sustained. Design considerations include:

- The range of suitable extended detention depths is 0.25-0.5 metres (providing suitable plant species are selected for deeper extended detention depths), depending on the desired operation of the wetland and target pollutant;
- The bathymetry (ground contours under the water) of the macrophyte zone should be designed to promote a sequence of ephemeral, shallow marsh, marsh and deep marsh zones in addition to small open water zones. The relative proportion of each zone will be dependent on the target pollutant and the wetland hydrologic effectiveness;
- The macrophyte zone is required to retain water permanently and therefore the base must be of suitable material to retain water (e.g. clay). If in-situ soils are unsuitable for water retention, a clay liner (e.g. compacted 300 millimetres thick) should be used to ensure there will be permanent water for vegetation and habitat;
- The bathymetry of the macrophyte zone should be designed so that all marsh zones are connected to a deeper open water zone to allow mosquito predators to seek refuge in the deeper open water zones during periods of extended dry weather;
- Particular attention should be given to the placement of the inlet and outlet structures, the length to width ratio of the macrophyte zone and flow control features to promote a high hydraulic efficiency within the macrophyte zone;
- Provision to drain the macrophyte zone for water level management during the plant establishment phase;

- For reed beds less than 100 metres in length, the gradient should be flat. For longer reed beds, the introduction of bed slope will compensate for the hydraulic gradient, and allow easier draining;
- The optimum treatment configuration is a wetland densely vegetated with species that provide a high density of stems in the submerged zone (thereby maximising the contact between the water and the surfaces on which microorganisms grow), while providing uniform flow conditions with no short circuiting;
- The main potential drawback to an overall densely vegetated system would be the reduction of dissolved oxygen in the near bottom water and the surface sediment layer. The presence of anaerobic sediment is desirable for denitrification, but careful consideration is required if densely planted systems can reduce dissolved oxygen so low that adverse effects can occur in freshwater receiving systems.

The macrophyte zone outlet structure needs to be designed to provide a notional detention time (usually 48 to 72 hours) for a wide range of flow depths. The outlet structure should also include measures to trap debris to prevent clogging.

Landscaping and Vegetation

Constructed wetlands are often located within accessible open space areas and can become interesting community features. Landscape design considerations are addressed further in **Section 13.4**.

Landscape design aims to ensure that the planting fulfils the intended treatment function as well as integrating with the surrounds.

Figure 13.4 Vegetation in the Grange Golf Course Wetland

Source: Courtesy of Adelaide and Mt Lofty Ranges Natural Resources Management Board

While individual plant species can have very specific water depth requirements, other species can be quite adaptive to growing across various zones over time. However, it is recommended that the suggested zones and plant groups are adhered to for planting purposes. Plant species suitable for the shallow marsh and ephemeral marsh wetland zones are equally suitable for edge planting (at equivalent depths) in sedimentation basins, ponds and lakes. Planting densities recommended should ensure that 70-80% cover is achieved after two growing seasons (two years).

The batters relate to the berms or embankments around the systems that may extend from the permanent pool water level to typically 0.5 metres above this design water level (i.e. within the extended detention depth). Plants that prefer a drier habitat should be planted towards the top of batters, whereas those that are adapted to more moist conditions should be planted closer to the water line.

It should be noted that the timing of planting is critical to optimise establishment of plants. Poor timing can result in excessive erosion, poor plant establishment, plant losses and additional costs.

Mosquitoes

To reduce the risk of high numbers of mosquitoes, there are a number of design features that can be considered. Not all of these will be feasible in any one situation, but they include (Gold Coast City Council 2007):

- Providing access for mosquito predators, such as fish and predatory insects, to all parts of the water body (avoid stagnant isolated areas of water);
- Providing a deep sump of permanent water (for long dry periods or for when water levels are artificially lowered) so that mosquito predators can seek refuge and maintain a presence in the wetland;
- Maintaining natural water level fluctuations that disturb the breeding cycle of some mosquito species, but be aware that this may suit other mosquito species;
- Where possible, incorporating a steep slope into the water, preferably greater than 30° or 3:1 horizontal to vertical. Note that steep edges may be unacceptable for public safety reasons, and a slope of up to 6:1 horizontal to vertical is generally used;
- Being aware that wave action from wind over open water will discourage mosquito egg laying and disrupt the ability of larvae to breathe;
- Providing a bathymetry such that regular wetting and drying is achieved and water draws down evenly so isolated pools are avoided;
- Providing sufficient gross pollutant control at the inlet such that human derived litter does not accumulate and provide a breeding habitat;
- Providing ready access for field operators to monitor and treat mosquito larvae;

- Ensuring maintenance procedures do not result in wheel rut and other localised depressions that create isolated pools when water levels fall;
- Ensuring overflow channels do not have depressions that will hold water after a storm event; and
- Immediately removing water weeds such as Water Hyacinth and Salvinia which can provide a breeding medium for some mosquito species whose larvae attach to these plants under water.

Each case has to be considered on its own merits. It may be possible that a well established constructed wetland will have no significant mosquito breeding associated with it, however changes in climatic and vegetation conditions could change that situation rapidly.

Maintaining awareness of mosquito problems and conducting regular monitoring for mosquito activity should be considered as a component of the management of constructed wetlands. Effective and environmentally sound control products are available for control of mosquito larvae in these situations.

Safety

Constructed wetlands need to be generally consistent with public safety requirements for new developments. These include reasonable batter profiles for edges to facilitate public egress from areas with standing water, and fencing where water depths and edge profile require physical barriers to public access.

The constructed fences can be substituted where possible by using dense edge plantings to deter public access to areas of open water. Children's playground equipment should not be located close to open water bodies.

The standard principles of informal surveillance, exclusion of places of concealment and open visible areas apply to the landscape design of wetlands. Where planting may create places of concealment or hinder informal surveillance, groundcovers and shrubs should not generally exceed 1 metre in height.

Maintenance Access

Maintenance access to a constructed wetland needs to be considered when determining the layout of a wetland system.

Inlet zones and gross pollutant traps require a track suitable for heavy machinery for removal of debris and desilting as well as an area for dewatering removed sediments.

Macrophyte zones require access to the areas for weeding and replanting as well as regular inspections.

Commonly, these access tracks can be incorporated with walking paths around a wetland system.

A defined hardstand area that provides for an 18-28 tonne excavator should be provided for full access to the inlet and macrophyte zones. It is critical to ensure the outlet for the macrophyte zone is located within easy reach of maintenance access and should not be located too far into the macrophyte zone.

Further information on the maintenance requirements of constructed wetlands is contained in **Section 13.7**.

Services

Wetlands tend to be located in or adjacent to open space or natural areas and are usually designed as large scale devices. Where they are located in open space areas, and within urban areas, designers should check the location of existing and proposed services including telecommunications, power, water and sewerage. Conflicts with existing or proposed services are to be avoided and can be addressed by changing the size, configuration and location of the wetland design or relocating the services.

13.4 Landscaping Considerations

Overview

If sited within accessible open space, constructed wetlands can be significant features within the built environment. Creative landscape design can enhance the appeal and sense of tranquillity that wetlands provide.

Landscape design aims to ensure that planting fulfils the intended water treatment function, as well as integrating with their surrounds.

Numerous opportunities are available for creative design solutions for specific elements. Close collaboration between landscape designer, hydraulic designer, civil/structural engineer and maintenance personnel is essential.

In parklands and residential areas, the aim is to ensure elements are sympathetic to their surroundings and are not overly engineered or industrial in style and appearance. Additionally, landscape design to specific elements should aim to create places that local residents and visitors will come to enjoy and regard as an asset.

Objectives

Landscape design of wetlands can have the following key objectives:

- Integrate the planning and design of constructed wetlands within the host natural and/or built environment;
- Ensure the wetland planting strategy is based on wetland design depths/zones to address runoff quality objectives and targets with the structural characteristics to perform particular treatment processes (e.g. well distributed flows, enhance sedimentation, maximise surface area for the adhesion of particles and provide a substratum for algal epiphytes and biofilms);
- Provide appropriate fringe plantings that promote habitat for fauna;
- Incorporate Crime Prevention Through Environmental Design (CPTED) principles;
- Provide other landscape values, such as shade, amenity, character and place making.

Context and Site Analysis

Comprehensive site analysis should inform the landscape design as well as road layouts, maintenance access points and civil works. Existing site factors such as roads, buildings, landforms, soils, plants, microclimates, services and views should be considered.

Constructed wetlands can have some impact on the available open space within new developments and considerable landscape planning needs to ensure that a balanced land use outcome is provided. Opportunities to enhance public amenity, education and safety with viewing areas, pathway links, picnic nodes, interpretive signage/art and other elements should be explored to further enhance the social context of constructed wetlands.

Landscape treatments should respond to the local context of the site within the Greater Adelaide Region, in particular planting types as they relate to the different vegetation communities in the region.

Wetland Siting and Shapes

Constructed wetlands need to integrate effectively into the surrounding existing landscape. The arrangement of the wetland basin and high flow bypass should be designed early in the concept design phase, to ensure that amenity of open space is enhanced.

The final shape of a wetland should provide landscape opportunities to create alternate useable spaces/recreation areas. Often different shapes to wetland edges can make pathway connections through and around these recreation areas more convenient and enhances the community perception of constructed wetlands.

Crossings

Given the size and location of wetland systems, it is important to consider if access is required across the wetland as part of an overall pathway network and maintenance requirement. Relevant Australian Standards should be referenced for access paths and decks within and around wetlands.

Pathways and bridges across planted earth bunds can be the best way of getting across or around wetlands. The materials on the bridge and pathways should be low maintenance and not impede hydrological flows. Recycled materials should be utilised where possible.

Figure 13.5 Boardwalk at Laratinga Wetland, Mt Barker

Source: Courtesy District Council of Mt Barker

High Flow Bypass Channel

The high flow bypass channel will convey flood waters during peak storm events. As these elements are generally turfed, it is worthwhile investigating the recreation opportunities offered at times outside of flood events. Designers should also investigate opportunities for locating trees and other vegetation types within the bypass channel. Provided hydraulic efficiencies can be accommodated, grassed mounds and landform grading of the embankment edge could also be explored to add variation and interest.

Viewing Areas

In parkland areas, turfed spaces within barrier fencing offer a simple low maintenance solution to incorporate a viewing area. Constructed decks may be appropriate in more urbanised areas. Hardwood timber construction should generally be avoided due to its inherent life cycle costs. Viewing areas should be located with a minimum distance of 5 metres separating the viewing area from the water body, so that wildlife feeding is discouraged.

Fencing

Where fences are required, layout and design of fencing is important in creating an overall attractive landscape solution. Fence styles need to respond to functional requirements but also the contextual setting (e.g. if it is an urban residential or open space/parkland area). Products designed for domestic gardens or industrial applications should generally be avoided. By specifying a black finish, and allowing for a screening garden in front of fences, the visual impact can be greatly reduced.

Appropriate Plant Selection

Between the macrophyte zone and the top of the embankment, trees, shrubs and groundcovers can be selected. Important considerations include:

- Selecting groundcovers, particularly for slopes greater than 1 in 3, with matting or rhizomataceous root systems to assist in binding the soil surface during the establishment phase;
- Preventing macrophyte zone plants from being shaded out by minimising tree densities at the water's edge and choosing species that allow sunlight to penetrate the tree canopy;
- Locating vegetation to allow views of the wetland and its surrounds while discouraging the public from accessing the water body;
- Selecting groundcovers which are capable of tolerating periodic inundation during extended detention.

Parkland vegetation may be of a similar species to the embankment's littoral vegetation and layout, to visually integrate the wetland with its surrounds. Alternatively, vegetation of contrasting species and/or layout may be selected to highlight the water body as a feature within the landscape.

13.5 Design Process

The design process and procedure for constructed wetlands includes a number of key steps, including:

- Assess site suitability (including site constraints and opportunities):
  - Open space, recreation and landscape linkages and requirements
  - Existing flora and fauna species
  - Services
  - Potential for site contamination
  - Soil properties
  - Catchment characteristics
  - Groundwater levels
  - Treated water reuse possibilities;
- Determine the design objectives and targets;
- Consult with council and other relevant authorities;
- Undertake a concept design:
  - Topographical survey of the site
  - Preliminary geotechnical survey
  - Design criteria based on water quality and quantity objectives and targets
  - Design flows based on catchment characteristics
  - Gross pollutants considered
  - Opportunities to minimise/negate greenhouse gas emissions of design and operation
  - Inlet zone layout (i.e. sedimentation basin design)
  - Macrophyte zone layout (i.e. extended detention depth, area of macrophyte zone, hydraulic efficiency)
  - Outlet and connection structures (including water level control)
  - Bypass weir
  - Verification of design performance (e.g. water quality or hydraulic modelling)
  - Recreational and educational aspects
  - Maintenance and access
  - Identify and propose mitigation of environmental issues on site
  - Cost estimate;

- Approvals process:
  - Local government
  - Environment Protection Authority
  - Natural Resources Management Board
  - Department of Water Land and Biodiversity Conservation
  - Department of Environment and Heritage;
- Undertake detailed design:
  - Detailed design of civil works
  - Additional geotechnical, hydrological and/or hydrogeological investigations
  - Detailed design drawings (including civil, landscape and recreational works)
  - Detailed design of relocation of services
  - Detailed cost estimate and schedule of quantities
  - Procurement plan
  - Planting plan and vegetation specification
  - Identify monitoring requirements
  - Design report;
- Check the design objectives;
- Prepare a construction plan; and
- Prepare a maintenance plan.

It should be noted that not all of the steps detailed above will be required for each wetland design.

Several elements of the design process are discussed briefly below. The general design process for all WSUD measures is discussed in **Chapter 3** of the Technical Manual.

Detailed constructed wetland design processes are contained in various publications contained in **Section 13.11**. The information obtained from interstate references should be adapted for the Greater Adelaide Region.

Site Suitability

WSUD responds to site conditions and land capability, and cannot be applied in a standard way. Careful assessment and interpretation of site conditions is therefore a fundamental part of designing a development that effectively incorporates WSUD.

Constraints and opportunities for the wetland must be identified and considered. In the Greater Adelaide Region, these factors are likely to include:

- Land availability, including future land use plans;
- Types and forms of pollutants generated in the catchment (e.g. dissolved nutrients, gross pollutants, toxicants, salinity and sediment);
- Pollutant delivery (e.g. mostly diffuse, base flows, first flush events, and timing of pollutant arrival);
- Geology/hydrogeology (e.g. groundwater levels and quality, aquifer suitability for MAR);
- Hydrology (e.g. rates, frequency and volume of runoff, environmental flow requirements)
- Topography (e.g. very flat or steep site);
- Site specific constraints (e.g. environmental, conservation and heritage issues, neighbouring land uses);
- Location of service infrastructure (e.g. roads, sewerage, water and gas pipelines, and telephone and power lines); and
- End use of the treated water (e.g. delivery into downstream waterways or reuse as irrigation water).

In particular, the proximity of the proposed wetland to residential areas needs to be considered in the selection and design of this WSUD measure.

Neighbouring communities will need to be consulted on the appearance, functionality and role of the constructed wetland. There are also safety concerns where the wetland is built in a publicly accessible area.

Objectives and Targets

Before the commencement of the design process, the objectives and targets for the constructed wetland should be established. Objectives include:

- Environmental benefits (such as water quality improvement, detention, retention and erosion control);
- Habitat value (enhancing biodiversity and conservation);
- Aesthetic, educational and recreational values; or
- Greenhouse gas emission minimisation/negation.

In setting objectives and targets, it is important to consider key State Government and council strategies and plans (such as strategic plans and stormwater management plans).

It is important to specify the contaminants that an urban water treatment wetland is designed to treat, as effective treatment of different contaminants can require markedly different detention times within the wetland.

The most common design priority for vegetated wetlands for the treatment of urban runoff will be the removal of:

- Sediments;
- Toxic substances including hydrocarbons and dissolved metals, and other toxic substances associated with fine particulate matter; and
- Nutrients.

Suspended solids are at one end of the treatability spectrum and require a relatively short detention time to achieve a high degree of removal, although fine particulate matter, which makes up a small proportion of suspended solids, is much more difficult to remove.

At the other end of the spectrum are nutrients. Given sufficient space and time, wetlands are capable of removing nutrients to very low levels, but like any other treatment system their efficiency depends on their design and water characteristics.

Designs that remove toxic substances will also achieve good aesthetic outcomes as well as meeting desirable discharge targets and some reduction of nutrients and human pathogens.

Further information on objectives and targets can be found in **Chapter 3** of the Technical Manual.

Consultation with Council and Other Relevant Authorities

The designer (or applicant) should liaise with civil designers and council officers prior to proceeding any further to ensure:

- The constructed wetland will not result in water damage to existing services or structures;
- Access for maintenance to existing services is maintained;
- No conflicts arise between the location of services and WSUD measures; and
- The objectives and targets are consistent with council directions stated in documents such as strategic plans and stormwater management plans.

The council will also be able to advise whether:

- Development approval is required and, if so, what information should be provided with the development application;
- Any other approving authorities should be consulted; and
- Any specific council requirements need to be taken into consideration.

Land and asset ownership issues are key considerations prior to construction of a WSUD measure, including wetlands. A proposed design should clearly identify the asset owner and who is responsible for maintenance, and this aspect should also be discussed during a meeting with the local council.

13.6 Design Tools

Numerous design tools are available for the concept and detailed design of constructed wetlands as detailed in **Chapter 15** of the Technical Manual.

The modelling tools which are able to assist include:

- MUSIC;
- EPA SWMM;
- XP-SWMM;
- WaterCress;
- Drains;
- Hec-Ras; and
- E2.

Design Flows

A range of hydrologic methods can be applied to estimate design flows.

If the typical catchment areas are relatively small, the rational method design procedure is considered to be a suitable method for estimating design flows.

However, if the constructed wetland is to form part of a retention basin, or if the catchment area to the wetland is large (> 50 ha), then a full flood routing computation method needs to be used to estimate design flows.

Simulations using computer models are often undertaken to optimise the relationship between detention time, wetland volume and hydrologic effectiveness of the constructed wetland, to maximise treatment given the volume constraints of the wetland site.

Water Quality Performance

The use of the model MUSIC can be utilised to optimise the conceptual design of a constructed wetland and to demonstrate its performance against the targets.

Further information on MUSIC is available in **Chapter 15**.

Figure 13.6 Greenfields Wetlands, City of Salisbury

Source: Courtesy of City of Salisbury

13.7 Construction Process

In the context of a large development site, and associated construction and building works, delivering constructed wetlands and establishing vegetation can be a challenging task. Constructed wetlands require a careful construction and establishment approach to ensure the wetland establishes in accordance with its design intent.

An example Construction Checklist is included in **Appendix A**. However, these forms should be adapted on a site-specific basis as the configuration and nature of constructed wetlands varies significantly.

Aspects of the construction process are discussed below.

Sediment and Erosion Control

Construction activities can generate large sediment loads in runoff which can smother wetland vegetation. Construction traffic and other works can also result in damage to constructed wetlands.

Sediment and erosion control is discussed below for those circumstance where the wetland has been constructed prior to or at the same time as other building activities on a site.

During the building phase of developments, temporary sediment and erosion control protective measures preserve the functional infrastructure of a constructed wetland against damage while also providing a temporary erosion and sediment control facility throughout the building phase to protect downstream aquatic ecosystems.

The inlet zone will essentially form a sedimentation basin which will reduce the load of coarse sediment discharging to the receiving environment. The inlet zone and the macrophyte zone should be disconnected to ensure the majority of flows from the catchment continue to bypass the macrophyte zone, thus allowing the wetland plants to reach full maturity without the risk of being smothered with coarse sediment. This means the macrophyte zone can be fully commissioned and made ready for operation once the building phase is complete.

At the completion of the building phase the inlet zone should be desilted, the disconnection between the inlet zone and macrophyte zone removed and the constructed wetland allowed to operate in accordance with the design.

Construction Tolerances

It is important to emphasise the significance of construction tolerances in the constructed wetland systems. Ensuring the relative levels of the control structures (inlet connection to macrophyte zone, bypass weir and macrophyte zone outlet) are correct is particularly important to achieve appropriate hydraulic functions.

Generally, control structure tolerance of plus or minus 5 millimetres is considered acceptable. Additionally, the bathymetry of the macrophyte zone must be free from localised depressions and low points resulting from earthworks. This is important to achieve a well distributed flow path and to prevent pools forming (potentially creating mosquito habitat) when the wetland drains. Generally, an earthworks tolerance of plus or minus 25 millimetres is considered acceptable.

Vegetation

The period of establishment and maintenance of vegetation within a wetland system is a critical phase of the wetland construction and operation process. To maximise the success of plant establishment in wetland macrophyte zones, specific procedures are required in site preparation, stock sourcing, vegetation establishment and maintenance including:

- Sourcing plant stock:
  - Lead times for ordering plants
  - Recommended planting systems/products;
- Topsoil specification and preparation:
  - Sourcing, testing and amendment
  - Topsoil treatments (e.g. gypsum, lime, fertiliser);
- Vegetation establishment:
  - Weed control
  - Watering
  - Water level manipulation.

Construction planning and phasing should endeavour to correspond with suitable planting months wherever possible. However, as lead times from earthworks to planting can often be long, temporary erosion controls (e.g. use of matting or sterile grasses to stabilise exposed batters) should always be used prior to planting.

To maximise the chances of successful vegetation establishment, the water level of the wetland system is to be manipulated in the early stages of vegetation growth.

Constructed wetlands, like most WSUD measures that employ soil and vegetation based treatment processes, require approximately two growing seasons (i.e. two years) before the vegetation in the systems has reached its design condition (i.e. height and density).

Bird Protection

During the early stages of wetland establishment, water birds can be a major nuisance due to their habit of pulling out recently planted species. Interlocking planting systems can be used, as water birds find it difficult to lift the interlocking plants out of the substrate unlike single plants grown in tubes.

13.8 Monitoring and Maintenance

Monitoring

To determine whether the wetland is performing as expected, a monitoring program detailing hydrology and the water quality of inflow and outflow is recommended. At a minimum, the following monitoring should be undertaken:

- Monitoring of surface water levels and flow pathways levels in the wetland to ascertain whether the actual wetland hydrology matches that of the design intent;
- Monitoring of the groundwater levels to identify any changes; and
- Monitoring of the inflow and outflows for total suspended solids and nutrients in low flow and high flow periods.

Maintenance

A detailed maintenance plan should be developed that specifies short and long-term maintenance of the constructed wetland. For simple wetlands, the plan may only need to specify how often to maintain and inspect the banks, when to inspect inlet and outlet structures for signs of clogging and when to remove sediment.

More complex wetland designs with mechanical devices, such as valves or pumps, may require much more detailed maintenance plans, including manufacturers' maintenance recommendations.

The most intensive period of maintenance is during the plant establishment period (first two years) when weed removal and replanting may be required. It is also the time when large loads of sediments could impact on plant growth, particularly in developing catchments with poor building controls.

Operational maintenance falls into a number of different categories, but the two main areas are:

- Aesthetic/nuisance maintenance – important primarily for public acceptance of WSUD measures, and because it may also reduce functional maintenance activities; and
- Functional maintenance – includes routine (preventive) and corrective maintenance and is important for performance and safety reasons.

These two areas can overlap at times and are equally important. Both forms of maintenance should be combined into an overall maintenance program.

Aesthetic Maintenance

Aesthetic maintenance primarily enhances the visual appearance and appeal of a wetland. An attractive wetland will more easily become an integral part of a community. Aesthetic maintenance is obviously more important for those wetlands that are very visible. The following activities can be included in an aesthetic maintenance program:

- Graffiti removal – the timely removal of graffiti will improve the appearance of the area around a wetland. Timely removal will also tend to discourage further graffiti or other acts of vandalism;
- Grass trimming – trimming of grass around fences, outlet structures, hiker/biker paths, and structures will provide a more attractive appearance to the general public. As much as possible, the design of wetlands should incorporate natural landscaping elements which require less cutting and/or trimming.
- Control of weeds – in situations where vegetation has been established, undesirable plants can be expected. These undesirable plants can adversely impact on the aesthetics of a wetland and send the wrong signals to the public about weed control. These undesirable plants can be removed through mechanical or chemical means.
- Miscellaneous details – careful and frequent attention to performing maintenance tasks such as painting, tree pruning, leaf collection, debris removal and grass cutting (where intended) will ensure the wetland maintains an attractive appearance.

Functional Maintenance

Functional maintenance is necessary to keep a water management system operational at all times. It has two components – preventive and corrective maintenance.

- Preventive maintenance

  Preventative maintenance is done on a regular basis. Tasks include upkeep of any moving parts, such as outlet drain valves or hinges for grates or maintenance of locks. Other examples of preventive maintenance include:

  - Grass mowing – actual mowing requirements should be tailored to the specific site conditions and grass type;
  - Grass maintenance – grass areas require limited periodic fertilising and soil conditioning in order to maintain healthy growth. Provisions may have to be made to re-seed and re-establish grass cover in areas damaged by sediment accumulation, runoff or other causes;
  - Vegetative cover – trees, shrubs, and other landscaping ground cover may require periodic maintenance, including fertilising, pruning, and weed and pest control.

Wetlands should be inspected at least twice per year during the first three years during both growing and non-growing seasons to observe plant species presence, abundance, and condition, bottom contours, and water depths relative to plans, sediment, outlet and buffer conditions

Vegetation needs to be maintained such that the flow management role of the wetland is maintained to ensure adequate flood protection for local properties and protection of the wetland ecosystem;

- Trash and debris – a regularly scheduled program (monthly or after rainfall events) of debris and trash removal will reduce the potential for outlet structures, trash racks, and other wetland components from becoming clogged and inoperable during storm events. In addition, removal of trash and debris will prevent possible damage to vegetated areas and eliminate potential mosquito breeding habitats. Disposal of debris and trash must comply with all local and regional control programs;
- Sediment removal and disposal – accumulated sediments should be removed before they threaten the operation or storage volume of a wetland. A dewatering area will be needed to allow the sediment to dry before disposal. Disposal of sediments also must comply with local and regional requirements;
- Mechanical components – mechanical components, for example valves and gates, should remain functional at all times. Regularly scheduled maintenance should be performed in accordance with the manufacturers' recommendations; and
- Wetland maintenance program – a maintenance program for monitoring the overall performance of the wetland should be established. It is important to remember that potentially large problems can be avoided if preventive maintenance is done in a timely fashion.

- Corrective Maintenance:

  Corrective maintenance is required on an emergency or non-routine basis to correct problems and restore the intended operation and safe function of the wetland. Corrective maintenance activities include:

  - Removal of debris and sediment – sediment, debris and trash which threaten the ability of the wetland to store or convey water should be removed immediately and properly disposed of in order to restore proper wetland function. If sediments are clogging a wetland component, the lack of an available disposal site should not delay removal of the sediments. Temporary arrangements should be made for handling the sediments until a more permanent arrangement is made.

- Structural repairs – repairs to any structural component of the wetland should be made promptly. Equipment, materials and personnel must be readily available so repairs can be performed at short notice. Where structural damage has occurred, the design and conduct of repairs should be undertaken only by qualified personnel.
- Dam, embankment and slope repairs – damage to dams, embankments and slopes must be repaired quickly. Typical problems include settlement, scouring, cracking, sloughing, seepage and rilling. Repairs need to be made promptly. If the wetland is to be dewatered, pumps may be necessary if there is no drain valve.
- Erosion repair – vegetative cover is necessary to prevent soil loss, maintain the structural integrity of the wetland and maintain its contaminant removal benefits. Erosion problems are likely to start as small problems and grow into larger problems. Corrective action can include reseeding programs, erosion control blankets, riprap, sodding or reduced flow through the area.
- Fence repair – fences can be damaged by any number of factors, including vandalism and storms. Timely repair will maintain the security of the site.
- Elimination of trees or woody vegetation – woody vegetation can present problems for dams or embankments as the root system of such vegetation can undermine dam or embankment strength. Vegetation, including root systems, must be removed from dams or embankments and the excavated materials replaced with proper material at a specified compaction (normally 95% of the soil's maximum density).
- General facility maintenance – if one wetland component is undergoing corrective maintenance, other components should be inspected at the same time to see if they also need maintenance. This may yield cost savings if equipment is already on site.

Maintenance Plan

All maintenance should be specified in a maintenance plan (and associated maintenance inspection forms) to be developed as part of the design procedure. Maintenance personnel and asset managers will use this plan to ensure the wetlands continue to function as designed. To ensure maintenance activities are appropriate for the wetland as it develops, maintenance plans should be updated a minimum of every three years.

The maintenance plans and forms should address the following:

- Inspection frequency;
- Maintenance frequency;

- Data collection/storage requirements (i.e. during inspections);
- Detailed clean out procedures including:
  - Equipment needs
  - Maintenance techniques
  - Occupational health and safety
  - Public safety
  - Environmental management considerations
  - Disposal requirements (of removed material)
  - Access issues
  - Stakeholder notification requirements
  - Data collection requirements (if any)
  - Design details.

An example Operation and Maintenance Inspection checklist is included in **Appendix A**. These forms should be developed on a site-specific basis as the configuration and nature of constructed wetlands varies significantly.

13.9 Approximate Costing

Costs for constructing wetlands can vary greatly depending on the configuration, location, site-specific condition (including hydrogeology, temporal patterns and seasonal temperature variations), volumes, flow rate and pollutant removal targets.

There is little available cost data for constructed wetlands in the Greater Adelaide Region. Typical construction costs presented in various reports range from approximately $500,000 to $750,000 per wetland hectare. The two key variables underpinning the construction costs are the extent of earthworks required and the types and extent of vegetation (Department of Environment WA 2004).

Annual maintenance costs have been reported to be approximately 2% of construction costs (Department of Environment WA 2004).

13.10 Case Studies

Breakout Creek Wetland, City of West Torrens

Breakout Creek is the last 3.5 km section of the River Torrens. It is an artificial channel constructed in 1938 to alleviate flooding caused in the wetlands and freshwater lagoons which formed behind the sand dunes where the Torrens meets the Patawalonga Creek and the Port River.

The riparian environment was used for horse grazing. The site was infested with feral and exotic plants and weeds, and the area was not available for community recreational use.

The area was therefore transformed into a wetland and community facility. The works extend approximately 500 metres up stream of the Henley Beach Road Bridge. Earthworks were completed in March 1999 and constructed with funding entirely from the former Torrens Catchment Water Management Board (now Adelaide and Mount Lofty Ranges Natural Resources Management Board).

Figure 13.7 Breakout Creek Wetland

The design of the wetland included detailed flood modelling to ensure there was no additional risk of flooding due to the works. Key features of the Breakout Creek instream wetland design are:

- A rock chute/weir at the downstream end to maintain a large pool of still water (deepest point 3 metres, approximate volume 20,000 cubic metres);
- Secured snags and partly submerged logs in the permanent water pool to provide habitat and refuge for fish and birds;
- Extensive landscaping including locally indigenous vegetation; and
- Walkways and access paths appropriate for the flood prone location.

The site is managed by the City of West Torrens. The instream wetland has provided improved water quality downstream, particularly under low flow conditions.

A second stage of the project is planned. This will extend from Henley Beach Road through to Tapleys Hill Road, a distance of approximately 700 metres.

Warriparinga Wetland, Bedford Park

Warriparinga Wetland is an offstream wetland located adjacent to the Sturt River, in Laffers Triangle between Main South Road, Sturt Road and Marion Road in Bedford Park. The objective of the project was to enhance Laffers Triangle, particularly the Warriparinga Reserve, and to improve the water quality of the Sturt River.

The wetland comprises a series of four ponds with shallow edges, gently grading to a depth of 3 metres at the centre. The permanent volume of the wetland is 23 megalitres. The water level fluctuates above the permanent water level when the Sturt River experiences a flow increase above its base flow. The second pond includes an island to act as a refuge for birdlife and to create visual interest to the wetland landscape.

The average annual flow entering the wetlands is 8400 megalitres.

Figure 13.8 Warriparinga Wetland with Inlet and Trash Rack in Background

Source: Planning SA (2005)

Water is drawn from the Sturt River upstream of an oxbow bend. The inlet was carefully designed to ensure existing significant eucalyptus trees in the area would not be affected by the wetland construction. Sufficient flows are maintained down the Sturt River channel adjacent to the wetland by means of a low flow bypass. This ensures that existing trees and reed beds in this section of the river are not affected by diversions into the wetland.

Water levels in the wetland remain close to full during the winter months. During summer, the level drops by 400 millimetres in an average year.

The outlet for the wetland is located on the western bank of the Sturt River, immediately upstream of the commencement of the concrete lined section of the channel and is formed as a rock riffle area. Within the wetland, a series of rock weirs are constructed to ensure flow is evenly distributed as it flows between the ponds.

The wetland traps and removes contaminants including silt, nutrients, bacteria, heavy metals, oils and floating rubbish such as leaves and litter. The wetland removes approximately 100 tonnes of sediment and 50 kilograms of phosphorus each year.

A timber boardwalk is located along the southern boundary of the site. The area around the wetland and the ponds themselves are planted and landscaped, with all plantings being indigenous. Twenty varieties of reeds and aquatic plants were placed in the ponds and have colonised the edges of the water bodies. More than 900 trees and scrubs were planted in the area around the wetland to create a natural landscape and provide habitat for birds and wildlife.

The wetland operates in conjunction with various gross pollutant removal and treatment facilities in the Sturt River catchment.

Urrbrae Wetland, City of Mitcham

The Urrbrae Wetland is located at Urrbrae Agricultural High School, Cross Road at Netherby.

In the early 1990s the City of Mitcham and the Urrbrae Agricultural High School were independently investigating a wetland project in the Urrbrae catchment. The council was seeking to alleviate a long standing flooding problem along Cross Road while the school was seeking to broaden its environmental studies curriculum, and address regular flooding on its farmland where the wetland is now situated.

A joint working party was created to prepare a concept plan for a teaching wetland which would also serve as a runoff detention basin.

Figure 13.9 Urrbrae Wetland

Work on the project commenced in June 1996.

Relevant facts about the project include:

- Urrbrae Agricultural High School and the City of Mitcham are joint operators of the wetland;
- Average annual volume of runoff treated is between 300-400 megalitres;
- The wetland was constructed in 1996 and first filled in 1997;
- Maximum depth of ponds is 3 metres;
- The ponds cover an area of 3 hectares; and
- The catchment area is approximately 3.75 square kilometres.

This unique urban wetland:

- Reduces the frequency of local flooding;
- Removes suspended solids by sedimentation;
- Physically filters runoff through dense reed beds;
- Removes pollutants such as agricultural fertilisers and other chemicals which attach to soil particles and are removed by sedimentation and filtration;
- Destroys pathogens through exposure to the ultraviolet rays of the sun and the feeding of zooplankton on pathogens;
- Filters out debris by operation of gross pollutants traps at the inlets;
- Improves the quality of water entering Brownhill Creek and ultimately the Patawalonga basin;
- Provides a valuable research and teaching resource for the school and community; and
- Creates a protected habitat for locally indigenous flora and fauna.

Since the initial construction of the wetland, modifications have been made to increase its performance. The first trash control systems installed at the wetland struggled to manage the amount of water and materials moving in the catchment. Water would often pour over the trash racks, taking much of the rubbish with it and also eroding the area around the racks.

After such events, quantities of organic material entered the wetland and moved through the catchment. Frequently the high velocities would carry sediments into the ponds.

To overcome these problems, work began in late 2003 on enlarging the inlet structures and installing more trash racks to improve collection of the organic litter and gross pollutants. To improve sediment capture, settling ponds external to the wetland proper were constructed at both of the inlets to the wetland.

To enable regular cleaning out of the sediment settling ponds, the flow of water is controlled at the point of entry from the street by the installation of drop log gates that can be slid down to bypass the ponds that are being worked on.

13.11 Useful Resources and Further Information

Fact Sheets

www.waterwatchadelaide.net.au/index.php?page=wetland-fact-sheets

Waterwatch Wetland fact sheets

www.goldcoast.qld.gov.au/attachment/wetlands_fact_sheet.pdf

Wetlands fact sheet (Gold Coast)

www.brisbane.qld.gov.au/bccwr/lib184/wsud%20practice%20note%2006%20constructed%20wetlands.pdf

Constructed Wetlands Practice Note (Brisbane)

Legislation Information

www.legislation.sa.gov.au/LZ/C/POL/ENVIRONMENT%20PROTECTION%20(WATER%20QUALITY)%20POLICY%202003/CURRENT/2003.-.UN.PDF

Environment Protection (Water Quality) Policy 2003

www.legislation.sa.gov.au/LZ/C/POL/ENVIRONMENT%20PROTECTION%20(NOISE)%20POLICY%202007/CURRENT/2007.-.UN.PDF

Environment Protection (Industrial Noise) Policy 1994

www.epa.sa.gov.au/pdfs/info_construction.pdf

EPA information sheet on Construction Noise

www.epa.sa.gov.au/pdfs/info_noise.pdf

EPA information sheet on Environmental Noise

www.epa.sa.gov.au/pdfs/building_sites.pdf

EPA Handbook for Pollution Avoidance on Building Sites

www.epa.sa.gov.au/pdfs/bccop1.pdf

Stormwater Pollution Prevention Code of Practice for the Building and Construction Industry

Design Information

www.melbournewater.com.au/content/library/wsud/melbourne_water_wetland_design_guide.pdf

Constructed Wetland Systems Design Guide for Developers (Melbourne)

Modelling Information

http://waterbydesign.com.au/musicguide/

MUSIC Modelling Guidelines (Brisbane)

www.melbournewater.com.au/content/library/wsud/Guidelines_For_The_Use_Of_MUSIC.pdf

MUSIC Input Parameters (Melbourne)

General Information

www.amlrnrm.sa.gov.au/watermanagementservices/aboutwater/aboutwetlands.aspx

About Wetlands

www.amlrnrm.sa.gov.au/watermanagementservices/constructedwetlandsasrschemes.aspx

Constructed Wetlands and ASR Schemes

www.amlrnrm.sa.gov.au/watermanagementservices/constructedwetlandsasrschemes/breakoutcreek.aspx

Breakout Creek Wetland

www.epa.sa.gov.au/xstd_files/Air/Report/mosquitoes.pdf

Mosquitoes in Constructed Wetlands

www.arbovirus.health.nsw.gov.au/areas/arbovirus/mosquit/freshwet.htm

Freshwater Wetlands – Mosquito Production and Management

www.wqra.com.au/water_guidelines.htm

Water Quality Research Australian website and Australian Water Quality Guidelines

(Websites current at August 2010)

13.12 References

BMT WBM (2008). *National Guidelines for Evaluating Water Sensitive Urban Design (WSUD)*. March. www.nwc.gov.au/publications/index.cfm

Department of Environment WA (2004). *Stormwater Management Manual for Western Australia*. Perth, Western Australia. www.water.wa.gov.au/Managing+our+water/Stormwater+and+drainage/Stormwater+management+manual/default.aspx.

Gold Coast City Council (2007). *Water Sensitive Urban Design Guidelines*. June. www.goldcoast.qld.gov.au/gcplanningscheme_policies/policy_11.html#guidelines.

Hobart City Council (2006). *Water Sensitive Urban Design Site Development Guidelines and Practice Notes.* Hobart. www.hobartcity.com.au/content/InternetWebsite/Environment/Stormwater_and_Waterways/Water_Sensitive_Urban_Design.aspx.

IEAust (2006). *Australian Runoff Quality: A Guide to Water Sensitive Urban Design*. New South Wales.

Melbourne Water (2005a). *Constructed Wetland Systems - Design Guidelines for Developers.* Melbourne, Victoria. www.melbournewater.com.au/content/library/wsud/melbourne_water_wetland_design_guide.pdf.

Melbourne Water (2005b). *WSUD Engineering Procedures: Stormwater*. CSIRO Publishing.

Moreton Bay Waterways and Catchments Partnership (2006). *Water Sensitive Urban Design Technical Design Guidelines for South East Queensland*. http://waterbydesign.com.au/TechGuide/.

Planning SA (2005). *Guidelines for Urban Stormwater Management.* Adelaide, South Australia. http://dataserver.planning.sa.gov.au/publications/840p.pdf.

Upper Parramatta River Catchment Trust (2004). *Water Sensitive Urban Design, Technical Guidelines for Western Sydney*. Prepared by URS Australia Pty Ltd. www.wsud.org/tools-resources/

Wong, T. (1998). *Managing Urban Stormwater Using Constructed Wetlands.* Cooperative Research Centre for Catchment Hydrology. www.clearwater.asn.au/resources/302_1.pdf.

(Websites current at August 2010)

Appendix A
Checklists

The *Site Inspection Checklist* was developed specifically for these guidelines. The remaining checklists have been modified for South Australian designs and conditions from checklists and forms provided in Upper Parramatta River Catchment Trust (2004), Melbourne Water (2005b), IEAust (2006), Gold Coast City Council (2007) and BMT WBM (2008).

All parts of all checklists should be completed. Even if design checks or field inspections were not performed, it is important to record the reasons for this in the relevant checklists.

Constructed Wetlands

Site Inspection Checklist

Asset ID:		**Date of Visit:**	
Location:		**Time of Visit:**	
Description:			
Inspected by:			
Weather Conditions:			

Site Information:	**Comments**
1. Site dimensions (m)	
2. Area (m²)	
3. Current site use	
4. Existing structures: Age Condition Construction	
5. Sealed pavements (type and condition)	
6. Unsealed surface	
7. Drains: Presence Type Condition Outlet point	
8. Surface runoff	
Site Safety:	**Comments**
1. Potential contamination sources	
2. Identify any confined spaces (indicate if specific training required for access)	
3. Environmental hazards (snakes, sun exposure, etc)	
4. Other hazards	

Photographs:	Comments
1. Number of photographs taken	
2. Location of stored photographs	
3. Any further information regarding photographs	
Local and Regional Information:	**Comments**
1. Topography	
2. Hydrology	
3. Adjacent sites (including current use, buildings, physical boundaries): North East South West	
Fieldwork Logistics:	**Comments**
1. Access (include width, height, weight restrictions)	
2. Other restrictions	
Other Information:	**Comments**
Attachments:	**Comments**

Sketch of Site

(on this page please provide a rough sketch of the site plan)

Constructed Wetlands

Construction Inspection Checklist (During Construction)

Asset ID:		**Date of Visit:**	
Contact During Site Visit:		**Time of Visit:**	
Location:			
Description:			
Inspected by:			
Constructed by:			
Weather Conditions:			

Items Inspected	Checked Y/N	Satisfactory Y/N
Preliminary works		
1. Erosion and sediment control plan adopted		
2. Limit public access		
3. Location same as plan		
4. Site protection from existing flows		
5. All required permits and approvals in place		
Earthworks		
6. Integrity of banks		
7. Batter slopes as plans		
8. Impervious (e.g. clay) base installed		
9. Maintenance access to whole wetland		
10. Compaction process as designed		
11. Placement of adequate topsoil		
12. Levels as designed for base, benches, banks and spillway (including freeboard)		
13. Check for groundwater intrusion		

Items Inspected	Checked Y/N	Satisfactory Y/N
14. Stabilisation		
Structural Components		
15. Location and levels of outlet as designed		
16. Safety protection provided		
17. Pipe joints and connections as designed		
18. Concrete and reinforcement as designed		
19. Inlets appropriately installed		
20. Inlet energy dissipation installed		
21. No seepage through banks		
22. Ensure spillway is level		
23. Provision of maintenance drain(s)		
24. Collar installed on pipes		
25. Low flow channel is adequate		
26. Protection of riser from debris		
27. Bypass channel stabilised		
28. Erosion protection at macrophyte outlet		
Vegetation		
29. Vegetation appropriate to zone (depth)		
30. Weed removal prior to planting		
31. Provision for water level control		
32. Vegetation layout and densities as designed		
33. Provision for bird protection		
34. Bypass channel vegetated		

Items Inspected	Checked Y/N	Satisfactory Y/N
Erosion and Sediment Control		
35. Disconnect inlet zone from macrophyte zone (flows via high bypass)		
36. Inlet zone to be used as sediment basin during construction		
37. Stabilisation immediately following earthworks and planting of terrestrial landscape around basin		
38. Silt fences and traffic control in place		
Operational Establishment		
39. Inlet zone desilted		
40. Inlet zone disconnection removed		
Comments on Inspection		
Actions Required		
1.		
2.		
3.		
4.		
5.		

Constructed Wetlands

Construction Inspection Checklist (Final Inspection)

Asset ID:		**Date of Visit:**	
Contact During Site Visit:		**Time of Visit:**	
Location:			
Description:			
Inspected by:			
Constructed by:			
Weather Conditions:			

Items Inspected	Checked Y/N	Satisfactory Y/N
1. Confirm levels of inlets and outlets		
2. Confirm structural element sizes		
3. Check batter slopes		
4. Vegetation planting as designed		
5. Erosion protection measures working		
6. Pre-treatment installed and operational		
7. Maintenance access provided		
8. Public safety adequate		
9. Check for uneven settling of banks		
10. Evidence of stagnant water, short circuiting or vegetation scouring		
11. Evidence of litter or excessive debris		
12. Provision of removed sediment drainage area		
13. Evidence of debris in high flow bypass		
14. Macrophyte outlet free of debris		

Comments on Inspection
Actions Required
1.
2.
3.
4.
5.
6.

Constructed Wetlands

Maintenance Checklist

Asset ID:		**Date of Visit:**	
Inspection Frequency:		**Time of Visit:**	
Location:			
Description:			
Inspected by:			
Weather Conditions:			

Items Inspected	Checked Y/N	Action Required (Details) Y/N
1. Sediment accumulation at inflow points		
2. Litter within inlet or macrophyte zones		
3. Sediment within inlet zone requires removal (record depth, remove if >50%)		
4. Overflow structure integrity satisfactory		
5. Evidence of dumping (building waste, oils etc)		
6. Terrestrial vegetation condition satisfactory (density, weeds etc)		
7. Replanting required		
8. Settling of erosion of bunds/batters present		
9. Evidence of isolated shallow ponding		
10. Damage /vandalism to structures present		
11. Outlet structure free of debris		
12. Maintenance drain operational (check)		
13. Resetting of system required		

Comments on Inspection
Actions Required
1.
2.
3.
4.
5.
6.