GREEN INFRASTRUCTURE CASE STUDY:

WETLAND AND STORMWATER REUSE - FIRST CREEK WETLAND, ADELAIDE BOTANIC GARDEN

Green infrastructure is a green network - of green spaces, street trees and other vegetation (including wetlands, rain gardens, and green walls and roofs) - strategically planned, designed and managed to support the liveability, sustainability and resilience of an urban area. Green infrastructure is integrated, connected and multifunctional. It is integrated with development and other infrastructure, it links existing and new green assets across the public and private realms, and it provides multiple social, economic and environmental functions. Green infrastructure is essential infrastructure for our cities and towns.

This is one of a suite of case studies demonstrating how various types of green infrastructure were planned, designed and delivered, how they're maintained, and the challenges and lessons along the way.

PROJECT OVERVIEW

Situated in what was an under-utilised part of the Adelaide Botanic Garden (ABG), near Hackney Road, First Creek Wetland is a beautiful, accessible, interactive and educational, constructed wetland ecosystem, and an integral part of a stormwater recycling scheme that will eventually supply all of the garden's irrigation needs. This will ensure that the gardens will be 'drought-proofed' and the risk of losing iconic trees during droughts will be minimised.

First Creek Wetland includes:

- Three wetland ponds – sedimentation pond, macrophyte pond and balance pond
- Pre- and post-wetland mechanical screening
- Two groundwater injection and extraction wells
- More than 90 species of native aquatic and terrestrial plants
- Sunken amphitheatre, observation deck, bridge, running water feature with uncommon water plants, 'cracked earth' stones, stepping stones and trails around and through the wetland
- Interpretive features and signs

ABOUT THIS SITE

ORGANISATION
Botanic Gardens of SA

SETTING
Public park

GREEN INFRASTRUCTURE FEATURES
Constructed wetland and stormwater recycling system

COST
$10 million.

The under-utilised grassed area in the Adelaide Botanic Gardens that is now the First Creek Wetland.

First Creek Wetland is a good case study in large-scale wetland design, construction and management in an urban catchment. It is also a good example of 'build it and they will come'with an average of 20,000 students visiting per year.

GREEN INFRASTRUCTURE FEATURES AND DESIGN CRITERIA

First Creek has been modified several times over the last 150 years but it has always been a key feature of the Adelaide Botanic Gardens. Prior to the creation of the wetland, First Creek overtopped its banks in this part of the garden about three or four times per year. Sediment and rubbish accumulated in the creek, which was unsightly and contributed to poor water quality.

The First Creek Wetland scheme was constructed to:

- Harvest, treat and store water from First Creek to replace mains water for irrigation and help mitigate floods
- Create wetland ecosystems with an interesting range of plants that are beautiful, highly accessible and can be used for educational purposes

It is expected that it will take up to 10 years of injection to reduce the salinity of the native groundwater and develop a freshwater leaks; in the aquifer. The aquifer is in fractured rock and the leakageis assumed to be 50% of the injected volume.

The annotated aerial photo on the next page shows how First Creek Wetland works:

1. First Creek enters the gardens from under Hackney Road. The catchment is 23 km^2 extending up to Cleland Wildlife Park in the Adelaide Hills
2. A small portion of the creek flow is diverted into a pipe through a screen, which keeps out larger debris
3. Diverted water then enters an underground litter trap, using a Continuous Deflection Separation (CDS) unit, which catches and holds more large debris
4. A Hydrobrake device after the CDS restricts flow rates into the wetlands (max. 25 L/s otherwise the quality of the water post the macrophyte pond would be too poor to send to the cartridge sand filter) thereby dampening peaks and minimising scour and resuspension of solids
5. The flow spreads out and slows down in the deeper sedimentation pond. Larger suspended solids drop out and settle
6. The gravity-fed 'macrophyte pond' uses aquatic plants to treat the water further: finer soil particles settle out and stick to biofilms on submerged surfaces; aquatic plants and microbes cycle carbon and nutrients; and sunlight kills harmful organisms in the open water. The deep sections increase retention time and provide a head of water for the pumps
7. Water cleaned by the macrophyte bed is pumped (7) through a cartridge sand filter (8) into two groundwater wells (9)
8. The sand filter removes any remaining particles to make sure the quality is suitable to inject into the aquifer
9. Treated water is pumped into the well (~100 m deep) for storage over winter in the fractured rock aquifer (underground saturated zones). In summer, groundwater is extracted from the same wells (9) and pumped to the 'balance pond' (10). This injection and extraction of groundwater is known as aquifer storage and recovery (ASR), which is a type of managed aquifer recharge (MAR)
10. Treated water is temporarily stored in the balance pond because the irrigation pumps (11) need water faster than the groundwater wells can supply
11. Irrigation pumps send water from the balance pond (10) to the irrigation pipes
12. Overflow pipes set the maximum water levels for the wetlands and connect each pond back into First Creek

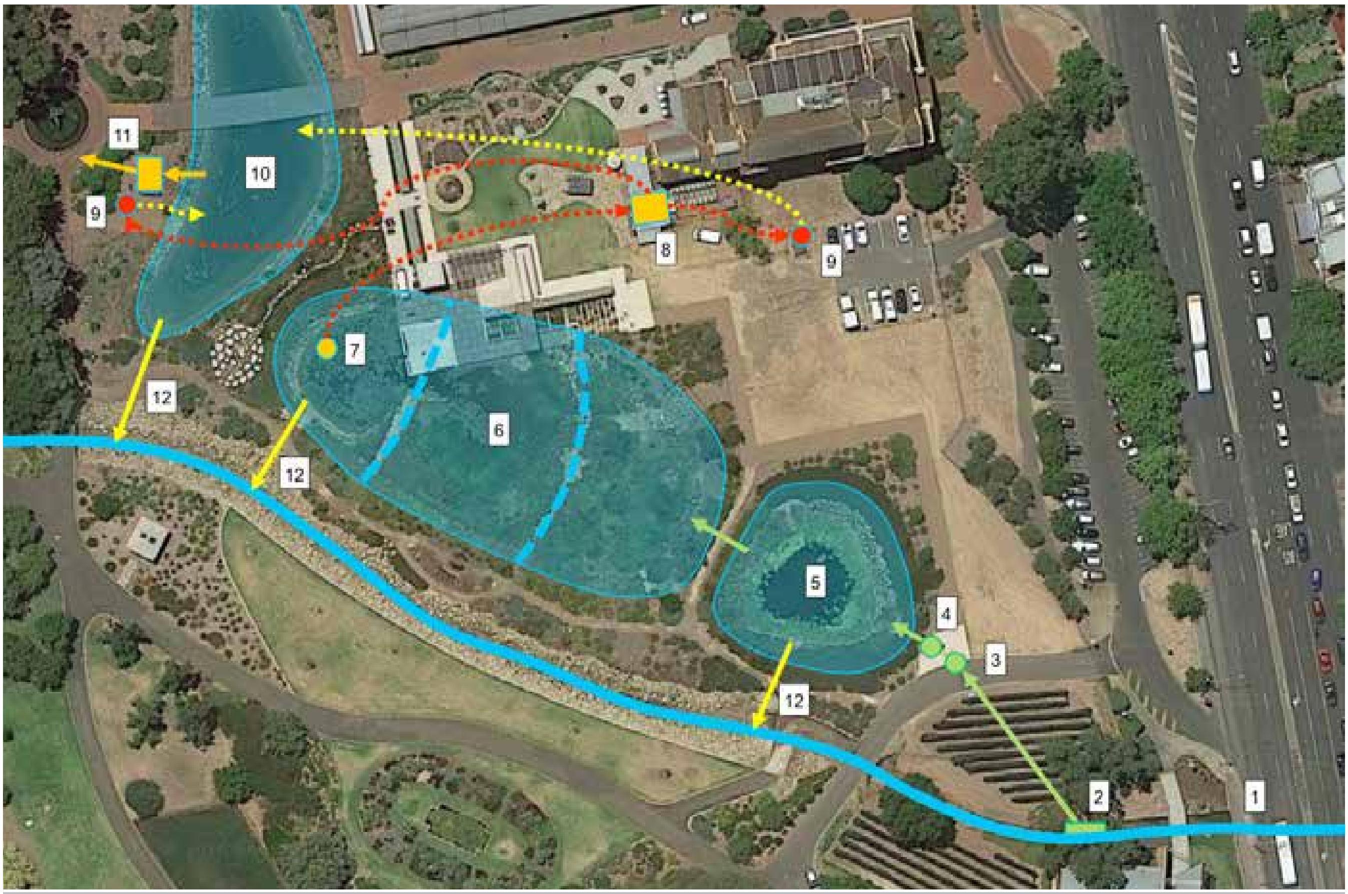
STORMWATER RECYCLING SCHEME FEATURES

LINEAR RESERVE

- Target ~100 ML/y stormwater reuse for irrigation
- Pre-wetland screens: Continuous Deflection Separation (CDS) gross pollutant trap (GPT)
- *Rocla Hydrobrake* device restricting inflows from First Creek to max. 25 L/s
- Sedimentation basin (approx. 450 m^2)
- Macrophyte pond (approx. 2,300 m^2) – shallow, intermediate and deep zones.
- Post-wetland screen and sand filter
- Injected into bedrock fractures
- Extracted and stored temporarily in the balance pond (approx. 1,200 m^2)

The sedimentation (top), macrophyte (middle) and balance (bottom) ponds of First Creek Wetland.

First Creek Wetland is a beautiful, accessible, interactive and educational wetland in the heart of the city that is an integral part of a stormwater recycling scheme that will one day provide all the gardens' irrigation needs.



A schematic diagram of First Creek Wetland at the Adelaide Botanic Garden. Numbers are explained in the text.

PLANT SPECIES SELECTION

Approximately 70 aquatic plant species and 20 terrestrial plant species were sourced from the ABG, State Flora, other plant suppliers and wild populations. The intention was to give visitors exposure to a wide range of Australian native aquatic and riparian plants with different life forms and visual effects (e.g. lillies, herbs, reeds, shrubs, trees).

Most plants used in and around the wetland are Australian natives and most are native to South Australia. There are exceptions such as the landscape feature plants Swamp lily (*Crinum pendunculatum*) and Lord Howe Island lily (*Dietes robsoniana*), which are native to the eastern seaboard, from north Sydney and Lord Howe Island, respectively.

Generally speaking more tolerant plants (e.g. reeds, sedges, rushes, grasses) have established well but broad-leafed plants such as Nardoo (*Marsilea drummondii*), Running marsh flower, Eel-grass (*Vallisneria sp.*), and Swamp pea (*Swainsona procumbens*) have not, and have been outcompeted. The only broadleaf plants that have established are Slender knot weed (*Persicaria decipiens*, pictured) and Blue-star creeper (*Pratia pedunculata*). They have, however, established in areas where they were not planted which may indicate that they colonised from seed or propagules from the creek or from elsewhere within the wetland via water movement or birds. Both plants are very tough and rapidly colonise in the wild (e.g. Slender knot weed proliferates in River Murray wetlands undergoing wetting and drying cycles).

Some of the less tolerant, rarer or more ecologically significant plants (both native and exotic) are contained in the concrete

tanks next to the amphitheatre, such as the rare South Australian Broad milfoil (*Myriophyllum apiculatum*, pictured), which has not established in the wetland.

Exotic papyrus is present at the garden in an isolated lake but it has not colonised the wetland. Care was taken to ensure that potentially weedy plants were not used and thus introduced to the River Torrens catchment. Care should be taken to avoid use of non-local, potentially weedy plants in all constructed wetlands in case of escape into natural waterways. It should also be noted that permits are required for the collection of native wetland plants under the *Native Vegetation Act 1991*.

A large number and diversity of water birds (for an urban environment) have been recorded at the wetland, including the Purple swamp hen (*Porphyrio porphyrio)*, pictured.

MONITORING AND OPERATIONS

The water levels in the wetland are controlled by the difference between gravity inflows and pumped outflow from the macrophyte pond through the sand filter to the injection point. The maximum water levels are also controlled by the overflow pipes that drain back to First Creek, unless First Creek overtops into the wetland, which it does occasionally. On rainy days the pumps are cycled (run) to manage flow.

The treated water needs to be carefully monitored to ensure that water being injected into the aquifers is of a quality to meet the EPA licence conditions for pH, turbidity and conductivity (salinity).

The target is to only inject water when the turbidity is less than 20 Nephelometric Turbidity Units (NTU). In order to achieve this, if turbidity is greater than 10 NTU for 30 minutes the operator gets a warning alarm; if the NTU is less than 15 for 30 minutes the pumps shut down automatically; and if turbidity is NTU greater than 50 the pumps shut down immediately. This prevents slugs of turbid water being injected into the aquifer. Spikes in turbidity usually occur on restarting the injection system or when the sand filter is backwashed. False alarms can occur if air bubbles enter the turbidity meter.

High conductivity has occasionally stopped injection as the operator does not want to go the expense of capturing, cleaning, storing and injecting water that is too saline for irrigation. Injecting has never been stopped due to pH being too high or too low.

SA Water approval required the former mains water connection to the irrigation system to be physically disconnected to prevent treated stormwater entering the mains water system. This means that the operator has to manually disconnect the recycled water supply and reconnect the mains water supply to change from using treated stormwater to using mains water for irrigation. As this requirement has now been superseded, back flow prevention valves will be installed in the future to make switching water sources easier.

The aim is to inject 200 ML/year of treated water so that 100 ML/year can be reliably extracted for irrigation use. Losses through the system means approximately 220 ML/year needs to be diverted from First Creek in order to reach the 100 ML target. In the first year (2014/15), a total of 33 ML was injected followed by 74.2 ML in the second year of operation (2015/16). Volumes of approximately 1.6 ML were extracted in each year. These volumes are expected to increase over time as the treatment capacity of the macrophyte pond increases and operational capacity improves.

Slender knot weed (**Persicaria decipiens**)

Broad milfoil (**Myriophyllum apiculatum**)

Purple swamp hen (**Porphyrio porphyria**) hunting in the wetland fringes.

Knob Sedge (**Carex Inversa**)

Before and after the establishment of the balance pond

KEY LESSONS

- Sediment loads are a major design consideration and have the potential to greatly limit opportunities to inject into aquifers for storage due to poor water quality. Managing sediment requires a catchment-scale approach.
- Integrating operational and maintenance considerations into the design process is essential to optimise stormwater recycling capacity, particularly when the wetland has multiple, possibly conflicting objectives.
- Diversion structures often need to be modified after a new stormwater recycling scheme has been operating for some time; therefore, the willingness and ability to make post-construction changes will greatly enhance the chances of success.
- Sequencing of devices that have a hydraulic impact need to be thoroughly considered before construction, and manufacturers should be engaged to optimise use of products.
- Wetland operators need to learn by doing and need the control to change what they need to change, particularly water levels and flow rates to optimise plant growth and water treatment.

CHALLENGES & LESSONS

- The majority of the plant species have established well, including some rare and endangered species. Volunteer Bullrush (*Typha spp*.) or Common reeds (*Phragmites australis*) need to be removed to prevent colonisation and potential dominance.
- Not all the submerged aquatic plants and those that rely on deep, permanent water have established as expected. This may be due to the imported top soils not being organic enough, turbidity being too high, inappropriate density of planting or other wetland establishment factors. Once the emergent plants that dominate the macrophyte pond have formed more mature beds and built up thatch, the establishment of submerged plants should be possible. Some rare and endangered aquatic plants grow in concrete display tanks near the amphitheatre but it is situated on the southern side of the deck wall and thus is not sunny enough to sustain some species that prefer high light conditions.
- Algal growth is a persistent problem. It is visually unappealing and interferes with plant growth, smothering leaves and plants that are growing underwater. An aerator was installed in the balance pond to turn over the water column and interrupt thermal layers (stratification), which are optimal algal growth conditions. The aerator operates all year and works best when the balance pond is kept full. An aerator has been installed into the sedimentation pond as well, for use in summer, to reduce the growth of algae. It is turned off during injection periods (winter) to prevent sediment re-suspension and allow the sedimentation pond to perform its primary function.

- Sediment loads are a major design consideration and have the potential to greatly limit opportunities to inject into aquifers for storage due to poor water quality. Sediment in the First Creek limits the opportunities for stormwater recycling. First Creek transitions from being lined to partially-lined to unlined multiple times along its length, which suggests that episodic scouring events (e.g. construction and other works in the catchment that coincide with runoff) lead to deposition and remobilisation cycles that effectively transport sediments downstream and result in significant sediment loads to the wetlands. Managing sediment requires a catchment-scale approach.
- Increasing automation reduces operator time. Originally the system was manually-operated. Partial automation has reduced operation time for simple tasks and enables the operator to focus on optimising performance.
- Adaptive management is essential. Water is being diverted from a catchment over which the system operator has no control and aquatic plants are being used as part of the water quality treatment process. Such systems are inherently dynamic and take time to mature and optimise.
- Diversion structure design changes. The original, plain intake pipe admitted large quantities of debris which, coupled with the high sediment loads, led to sediment depositing upstream of the weir (immediately downstream of the intake pipe) and advancing quickly upstream toward the intake pipe opening. In addition, there was no way to drain water impounded by the weir by gravity, which led to stagnation and sediment removal difficulties. After some trial and error, a new weir and sluice gate were constructed further downstream, which allow more sediment to accumulate before the intake pipe is affected. A new intake manifold was also constructed, allowing water to be admitted into the intake pipe from further upstream of the debris cage, and from different heights above the creek bed.
- Gross pollutant interceptor selection was important for maintenance costs. The strong focus on visual amenity led to installation of an underground gross pollutant trap (GPT) to prevent unsightly litter getting into the sedimentation pond. The original GPT selected by the designers was the smallest unit of a particular proprietary GPT that had to be cleaned by an eductor (vacuum) truck. This would have required a separate cleaning contract and more expense so the next biggest size GPT was installed instead with a removable litter basket, which can be craned out by the current contractor.
- The need to restrict the flowrate to 25L/s led to changes. To achieve this flowrate restriction, a Hydrobrake device was installed downstream of the CDS but backwater effects caused the CDS to fail to operate as intended resulting in sediment deposition outside the intended accumulation zone. To manage this, the inlet valve (immediately downstream of the diversion structure in First Creek) is left partly closed to restrict the flowrate; however, this has other implications (e.g. increased potential for blockages at that point)! With the benefit of hindsight this could have been done better, e.g. by screening the First Creek offtake (provided this wouldn't block the Hydrobrake) and installing the CDS downstream of the Hydrobrake.
- All wetlands leak: Most constructed stormwater treatment wetlands in and around Adelaide are lined with compacted clay, to keep the harvested and treated

Construction of First Creek Wetland in 2013 as seen from the top of the adjacent Bicentennial Conservatory.

water in, and keep shallow groundwater out. While a compacted-clay liners have a very low permeability, they can rarely be considered to be waterproof which is not a concern as long as the rate of leakage is very low. In this case, a structure was constructed over the top of the compacted clay liner before the liner's performance was adequately confirmed, which meant that when a leak was subsequently detected, getting access to that part of the liner to re-compact it was difficult. Water levels in the wetland are relatively stable now, particularly in winter, but do vary due to groundwater leakage. Also the groundwater levels used in the design were collected in 2006, during an extended drought period. When the drought broke and groundwater levels recovered, it was found that the groundwater level was considerably higher than thought and part of the balance pond was in the water table. A chemical polymer has since been used to seal the balance pond.

- Once clean, keep it clean. If First Creek Wetland was constructed again, it would not have the final balance pond open to the environment but instead use an underground tank to store water to feed the irrigation system. As it is, water that has been cleaned by the screens, wetlands and filters is made 'dirty' again when it is stored in the open balance pond. This would also prevent the problem of having to keep the balance pond full for visual amenity, which promotes algal growth and subsequent blockage of irrigation screens.

EDUCATION & COMMUNITY

Visitors are encouraged to interact with the wetland via the sunken amphitheatre, observation deck, bridge, 'cracked earth' stones, stepping stones and trails around and through the wetland, and interpretive signs that explain the wetland features. Fencing is not used to separate people from open water; rather spiky plants discourage visitors from venturing near the deeper pools.

An annual average of 20,000 students, from kindergarten to Year 12, use the education program based around the wetland. The educational trails are all based on the Australian Curriculum and align with the ABG's mission of connecting 'people with plants; and sharing 'stories' about plants, which support a teacher's unit of inquiry, whether it be science, maths, geography or Aboriginal and Torres Strait Islander histories.

A trail for Years 4-7, entitled 'Life in a Wetland' provides students with a unique first-hand experience about wetland habitats and their role in cleaning water.

The wetlands are co-located with the vegetable gardens that are also part of schools programs, and both areas are used by Garden Guides on their daily tours.

First Creek flows past the wetland with a maximum of 25 L/s diverted into the wetland.

Iron reeds sculptures featured in the wetland.

FUTURE OPPORTUNITIES

As mentioned, the intention is to eventually supply all of the garden's irrigation needs. At this stage, the focus is on harvesting and treating enough water to operate the extraction side of the stormwater recycling scheme. Harvested/treated and extracted volumes are expected to increase over time as the treatment capacity of the macrophyte pond increases and operational capacity improves.

A second trail, 'Wetland Science: Scientific Analysis of the ABG First Creek Wetland', is being developed to enable Middle School students to investigate the efficacy of the wetlands as a means of water purification and recycling.

In the future, Fluker Posts will be installed www.discoverycircle.org.au/projects/flukerposts/ as part of a citizen science initiative centred on visitors taking photos at these photo-points over time and uploading them to a website.

MAINTENANCE

The wetland is maintained by ABG's staff, including full time Horticultural Curator, and contractors. Maintenance activities include:

- Operating the pumps and pipes to optimise water treatment
- Inspecting plants and infrastructure
- Periodically cleaning the underground litter trap.
- Occasionally remove plant material to maintain adequate flow rates through the wetland
- Cleaning out the sedimentation pond once sediment accumulates to 50% of the construction depth. This is expected to be every few years.

Technical data is uploaded to the Department for Environment, Water and Natural Resources website for EPA licensing purposes.

FINANCIAL PARTNERS

This project was funded jointly by the Department of Environment, Water and Natural Resources, the Adelaide and Mount Lofty Ranges Natural Resources Management Board, and the Australian Government Water for the Future Initiative.

A rocky path over one of the weirs, complete with 'iron reeds' and signs entice those who want to (literally) get their feet wet.

PROJECT DELIVERY

ENGINEERING AND LANDSCAPE DESIGN BY
Sinclair Knight Merz (now Jacobs) and Taylor Cullity Lethlean

CONSTRUCTED BY
Building Solutions (SA)

MAINTENANCE
ABG and contractors

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FOR FURTHER INFORMATION

Adelaide Botanic Gardens **www.botanic.sa.edu.au**