Wicking up a Storm - wicking beds delivering resilient urban parklands

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Innovation is often born when ideas are brought together from different applications. The recipe for this idea came from a base knowledge in soil-water science, mixed with a historical Ethiopian farming technique and a sprinkling of sports field drainage technology. The method involved locally harvesting stormwater and directing to a shallow storage zone beneath a 1420m^2 turf kick and throw field. The stormwater passively irrigates the turf above providing 70% of the fields irrigation demand reducing both energy and potable water demands. The result is an admirably simple but integrated solution that delivers everything you could ask for in a sustainable landscape scheme; passive irrigation, stormwater treatment, an alternative water source and improved soil profiles for healthy turf and active use spaces.

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I. Introduction

The Gladstone Coal Exporters Maritime Precinct parkland (ñthe Parkland) is a major new civic parkland for the City of Gladstone located on the foreshore of Auckland Inlet. The Gladstone Ports Corporation vision for the parkland was to provide óa world-class waterfront urban parkland that is accessible for all residents, visitors and workers within Gladstoneô. Delivering on this vision required sustainable water management to help secure water supplies and provide for high amenity green landscapes despite the challenging climatic conditions.

Wicking bed technology has been used in dry, variable climates to support vegetation in many applications ranging from agriculture in Ethiopia to small scale urban farming within Australia. This approach involves storing water within an underground reservoir which is drawn into the active root zone by the surface vegetation using the natural process of soil capillary rise, driven by evapotranspiration. This approach is useful in dry climates as it can incorporate water harvesting which allows smaller rain events to be captured and stored with reduced evaporative losses.This paper presents a novel application of wicking bed technology applied at a large scale and incorporated into a sustainable landscape design for a Parkland in Gladstone.

II. Gladstone Climatic Conditions and Water Supply

Gladstoneôs sub-tropical climate characterised by seasonal mean annual rainfall of 850mm and high potential evapotranspiration rates results in drying conditions over much of the year. The Gladstone community and industry endured severe water restrictions during 2002 and 2003 (GAWB, 2009). Despite the level of Awoonga Dam currently being at 93% capacity, the current water supply network does not provide for long term water security. Climate change predictions from CSIRO suggest an overall reduction in annual rainfall for Gladstone with longer periods of dry weather (CSIRO, 2014; McEnvoy and Mullett, 2013). This coupled with an increasing population and industrial/port expansion will put pressure on reticulated water supplies. The Gladstone Area Water Board (GAWB) has undertaken strategic water planning and is currently advancing the proposal for the Gladstone-Fitzroy pipeline (http://www.gladstone-fitzroypipeline.com.au/), however alternative local sources of water that are available now, are more cost effective, have a lower energy and carbon footprint and reduce environmental impacts were a key driver in the development of the sustainable landscape strategy for the Parkland.

III. Sustainable Parkland Landscape Design

The parkland is located adjacent to Auckland Inlet and is primarily located on reclaimed land characterised by uncontrolled fill overlying soil and bedrock which have low fertility and poor drainage. The parkland location, soil profile, climate and water supply context drove the parkland design to meet a number of important outcomes - to recreate a soil profile to support a healthy landscape; to manage site runoff to protect Auckland Inlet; and to build resilience by reducing the reliance on potable water supplies.

A sustainable water management strategy was developed for the parkland which incorporates collection, treatment and re-use of local sources of roof water and stormwater to substitute use of potable water for suitable end uses including toilet flushing and passive landscape irrigation. Recycled water ñpurple pipeò was installed during construction to allow for the future connection of alternative water sources to further offset potable water supplies and drought proof the parkland. Vegetated swales, bioretention, rainwater tanks, permeable pavement and stormwater harvesting are all important components of the integrated parkland design. The following sections of this paper focus on the passive stormwater harvesting system as a novel application of wicking bed and sports field drainage technology.

IV. Stormwater Harvesting and Wicking Bed Design

The use of ówicking bedô technology provided a solution for storing locally harvested stormwater runoff and enabling irrigation of turf without the need for pumps to distribute water. Stormwater runoff from the site is collected and stored within a 300mm deep sand layer creating a sub-surface aquifer located below a large open lawn kick and throw area. The aquifer layer is positioned directly below the topsoil layer/plant root zone and stores water above field capacity (i.e. gravitational water). The pore spaces in the sand layer provide the storage space for the stormwater. The wicking bed uses the natural process of soil capillary rise, driven by evapotranspiration, to draw water reserves held in the aquifer to the active root zone. As the turf removes water from the soil it is replaced by water replenished from the storage below by capillary action thereby ensuring optimal soil moisture conditions for healthy turf growth. This enhanced moisture storage capacity extends the period of time that water is available to sustain healthy turf growth.

The depth and composition of the aquifer was governed by capillary rise distance and storage volume. A washed river sand with a grain size 0.15 - 0.5mm provided an expected capillary rise distance of 400-500mm (Lohman,1972; Ranjan and Rao, 2005) and a porosity of 47% (Trilab soil testing results). An aquifer depth of 300mm therefore ensured the replenishment of soil moisture to the topsoil layer even when the water level within the aquifer storage was low. *Cynodon dactylon* (CT2 Sports Couch) was selected for its deep root system (Kearns et. al, 2009) up to 60cm, climatic tolerance and wear and tear capabilities making it suitable for high usage kick and throw areas. As a turf variety with a known deep rooting depth it is expected that with the combination of deep roots and capillary rise it will have access to the full aquifer capacity.

ñStripò drains featuring porous paving covers, located adjacent to the access road and car park, forms an integral component of the wicking bed system. The strip drains are hydraulically efficient conveyance systems to deliver stormwater runoff to the wicking bed. They are composed of concrete drainage channel (300mm width), fitted with slotted uPVC pipe and back filled with clean aggregate. The strip drains are covered with porous paving providing a trafficable and aesthetically pleasing finish with a high flow capacity (http://www.dymonporouspave.com). This configuration provides hydraulically efficient drains to maximise the amount of runoff that is delivered to the wicking bed from small (and more frequent) rainfall events. This provides for regular ótop-upô of the wicking bed storage which is essential to ensure the wicking bed is operating at its optimal reliability. Flows greater than the capacity of the strip drains enter vegetated swales for filtering and conveyance. The porous pavement covers over the strip drains prevent litter and coarse sediment from entering the drains and wicking bed system. Roof water from shade structures is also conveyed into the wicking bed storage via pits fitted with porous pavement lids.

Stormwater is distributed through the wicking bed system via a network of 100mm slotted uPVC pipes and a layer of Atlantis 52mm flocells (Figure 1). This ensures a rapid and even distribution of water. Flush out points, in the form of up stand pipes, are provided to enable clean out and/or inspection of the distribution pipe network. If the subsurface storage fills completely, stormwater overflows via a series of overflow pipes set at the top of the storage zone (below the turf topsoil layer). This overflow system ensures that the turf layer and growing media above wonôt be submerged during rainfall events and also facilitates enhanced drainage of the turf soil layer. This efficient drainage, modelled on sports field drainage (http://www.atlantiscorp.com.au/index.php/atlantis-solutions/sports-field-solutions), results in a deep high-growth root zone for stronger more resilient turf. This facilitates quicker wear recovery and increases the usability of the kick and throw areas after heavy rainfall events (including improved access for mowing and maintenance).

The Gladstone wicking bed provides a low maintenance irrigation system that requires no imported energy for water collection and distribution. In addition, the nutrients within the stormwater will support turf growth, reducing the need for fertiliser applications and the uptake of stormwater and associated nutrients will reduce pollutant loads to Auckland Inlet.

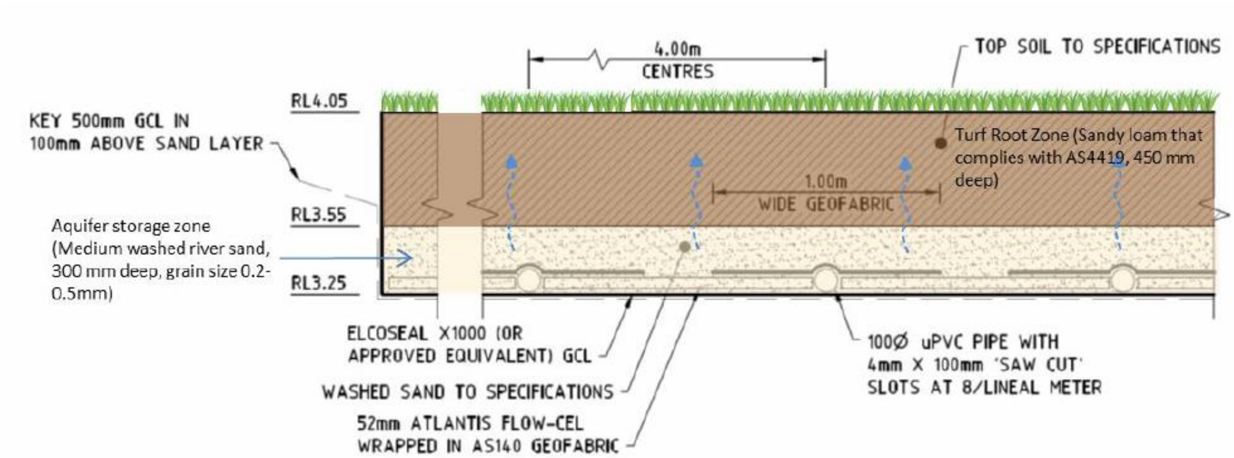

Figure 1. Typical section through wicking bed.

V. Irrigation Management & Monitoring

The wicking bed is integrated with the parklands broader automated irrigation control system enabling real time monitoring of performance. Data from soil moisture probes located in the turf growing media and from a water level sensor for the sub-surface aquifer is received though the central control system. A fail-safe automated ótop-upô system is also in place for extended dry periods. The operating philosophy is to only ótop-upô the wicking bed storage with potable water when a low ñtriggerò water level is reached or for adaptive management based on the real time data.

The water level sensors for the irrigation to-up system are positioned within a control pit adjacent to the wicking bed. The wicking bed water level control pit contains the following instrumentation:

1) Multitrode Water Level Sensor: For manual monitoring of the water level in the wicking bed storage ï visual monitoring can occur firstly at the Water Supply Control Panel (i.e. a visual bar-level LED); secondly at the Irrigation Central Computer
2) Float Valve: This water level control is programmed to automatically turn on or off and opens the inflow line once the water level reaches 100mm depth, shuts the inflow line once the water level reaches 200mm depth
3) Automatic Valve: This water level control valve will open on signal from the Irrigation Central Computer, either at a pre-set time or on manual instruction from the operator

If the Automatic Valve comes on but there is enough water in the wicking bed storage, then no more water comes in (as the Float Valve is closed). Water can only enter the wicking bed from the potable irrigation supply line if both the float valve and automatic valve are open.

In addition, Turf Guard soil moisture probes allow for manual monitoring (via the Irrigation Central Computer) of soil moisture levels.

VI. Modelling Method and Results

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) V6 was used to model the performance and reliability of this stormwater harvesting and wicking bed system. The following sections summarise the modelling parameters and results.

A. Rainfall data

Gladstone 6 minute rainfall data for an 11 year period (1980-1990) was used for the analyses. This rainfall data closely reflects the long term average rainfall data for the Gladstone area (Table 1) and is therefore suitable for the assessment of the wicking bed performance.

Table 1. Rainfall comparisons for MUSIC model and long term gauged data for Gladstone.

Rainfall statistics	MUSIC rainfall data (Gladstone 1980-1990)	Gauged rainfall data (Gladstone Radar 1957-2013)	% difference
Mean annual rainfall (mm)	909	894	1.7%
Rain days	108	99	8.7%
Evapotranspiration (2001)	1721	1719	0.1%

B. MUSIC model set-up

The MUSIC model was developed to represent the catchment and stormwater system which drains to the wicking bed (Figure 2).

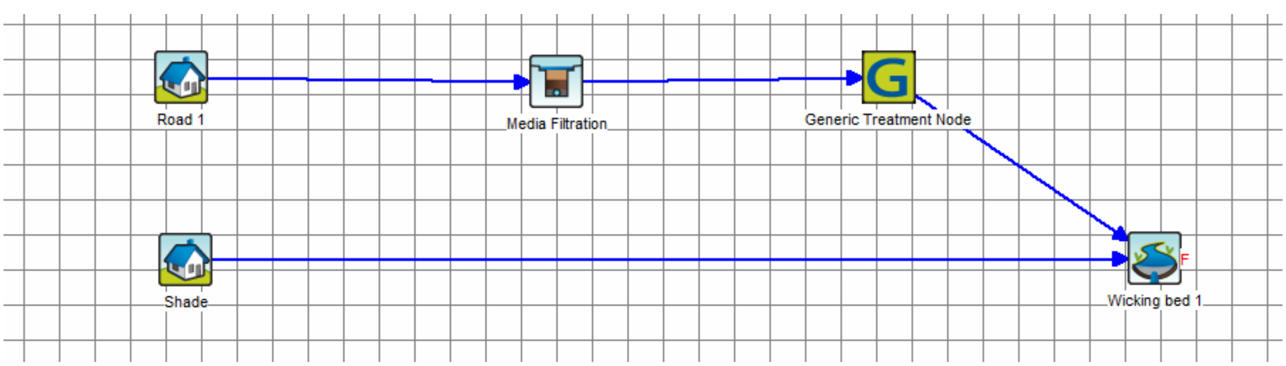

Figure 2. MUSIC model set-up.

The catchment which drains to the wicking bed consists of:

- a 6m wide ðheavy haulageô road which drains to the wicking bed via the óstrip drainsô which consists of a porous pavement cover over a 160 diameter slotted collection pipe (with a capacity of ~0.02 m^3/sec)
- a shade structure roof which drains directly to the wicking bed

Tables 2 and 3 summarise the modelling parameters used to represent the wicking bed and its contributing catchment and stormwater system.

Table 2. MUSIC source node parameters.

MUSIC source node	Area (m2)	% impervious	Soil parameters	Pollutant parameters
Road	1046	100	Urban residential	Industrial ï roads
Shade	112	100	Urban residential	Urban residential ï roof

*Soil parameters and pollutant parameters taken from MUSIC Modelling Guidelines (Water by Design, 2010)

Table 3. MUSIC treatment node parameters.

MUSIC parameters	Porous pavement	Slotted collection pipe	Wicking bed
MUSIC node	Media filtration node	Generic node	Pond
Surface area (m2)	50.4		1420
Extended detention depth (m)	0.1		0.1
Permanent pool volume (m3)			200
Exfiltration rate (mm/hr)	0		0
Evaporative loss as % of PET			41
Filter area (m2)	50.4		
Filter depth (m)	0.1		
Filter media particle diameter (mm)	1.00		
Saturated hydraulic conductivity (mm/hr)	3600		
Depth below underdrain (% of filter depth)	0		
Flow rate (m3/sec)		0.02	
K and C* values	default		default

C. Assessment and Results

To represent the seasonal variability in irrigation demand by the turf and the wicking bed top-up design, a detailed storage assessment was undertaken using a daily flux file generated from the MUSIC model. This assessment identified when the storage volume dropped below 1/3 of the storage capacity (66 kL) and top up was required to bring the storage volume to 2/3 capacity (132 kL). The assessment indicates that harvested stormwater stored within the wicking bed provides 70% of the total turf irrigation demand and that top-up is only required 4-5 times per year on average (i.e. 50 times over the 11 year period) resulting in a potable water saving of 7,690 kL over the 11 year period. Figure 3 highlights the frequency of the top-up events over the 11 year modelled period. Figures 4 to 6 show in detail how the top-up is triggered and helps to sustain the storage volume during times of limited rainfall for two of the modelled years with differing rainfall patterns.

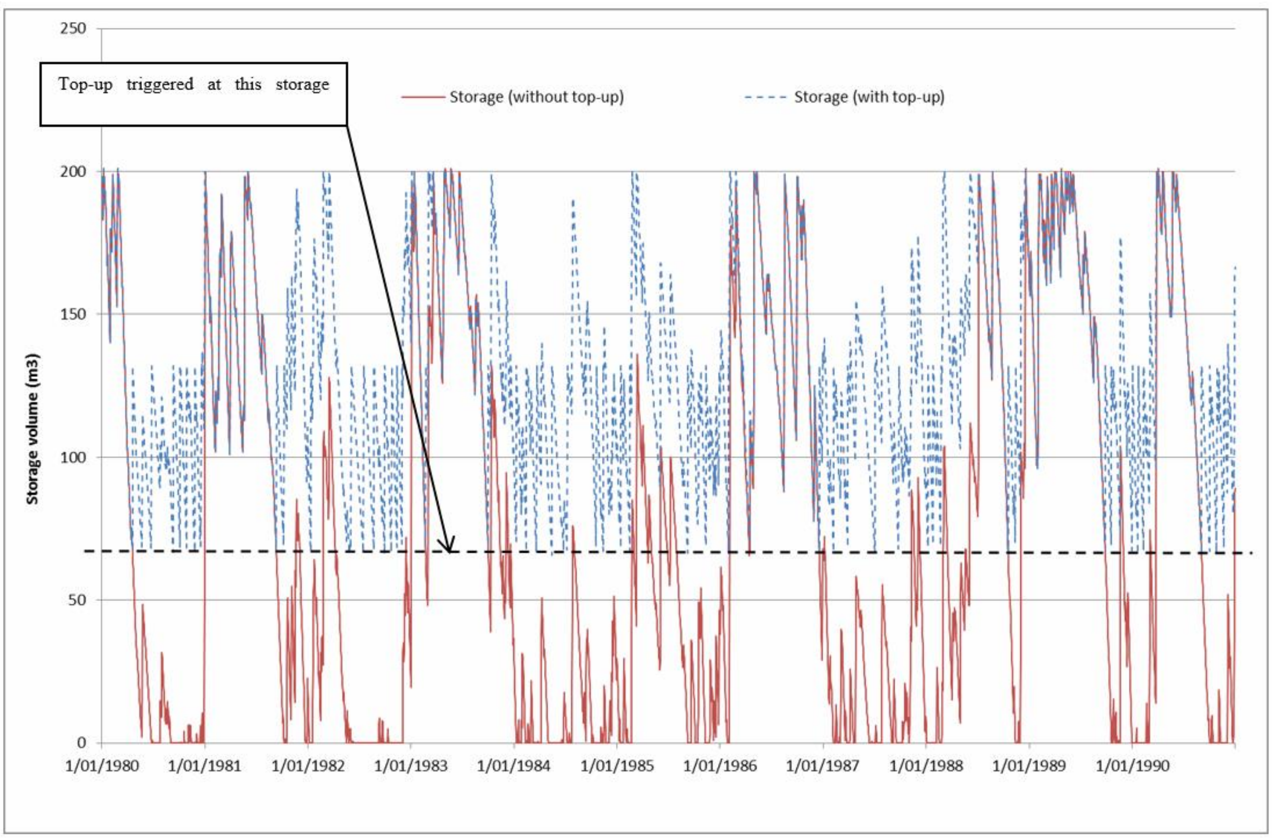

Figure 3. Storage volume comparison for wicking bed, with and with-out top up.

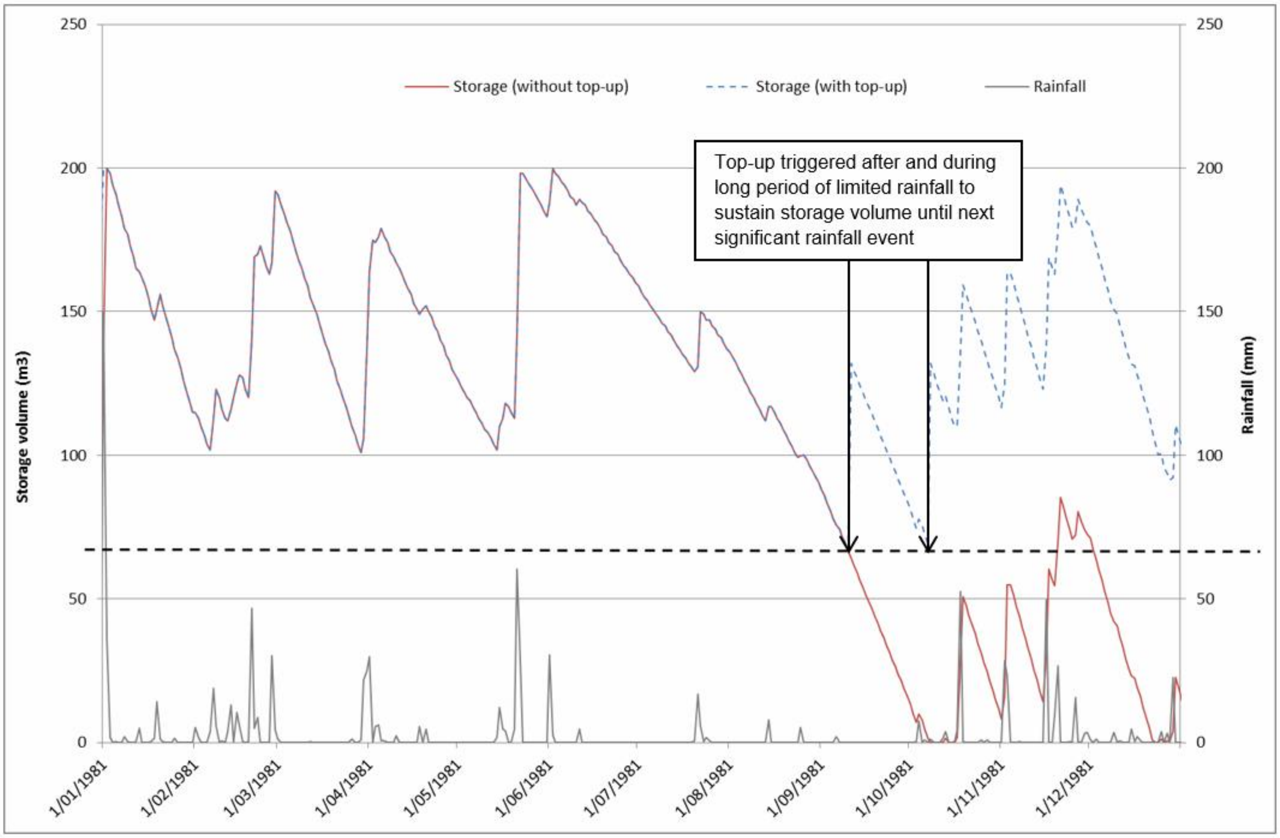

Figure 4. Storage volume comparison for wicking bed, with and with-out top up for one of the modelled years with an average rainfall (966 mm), highlighting how top-up helps to sustain storage volumes during periods of low rainfall.

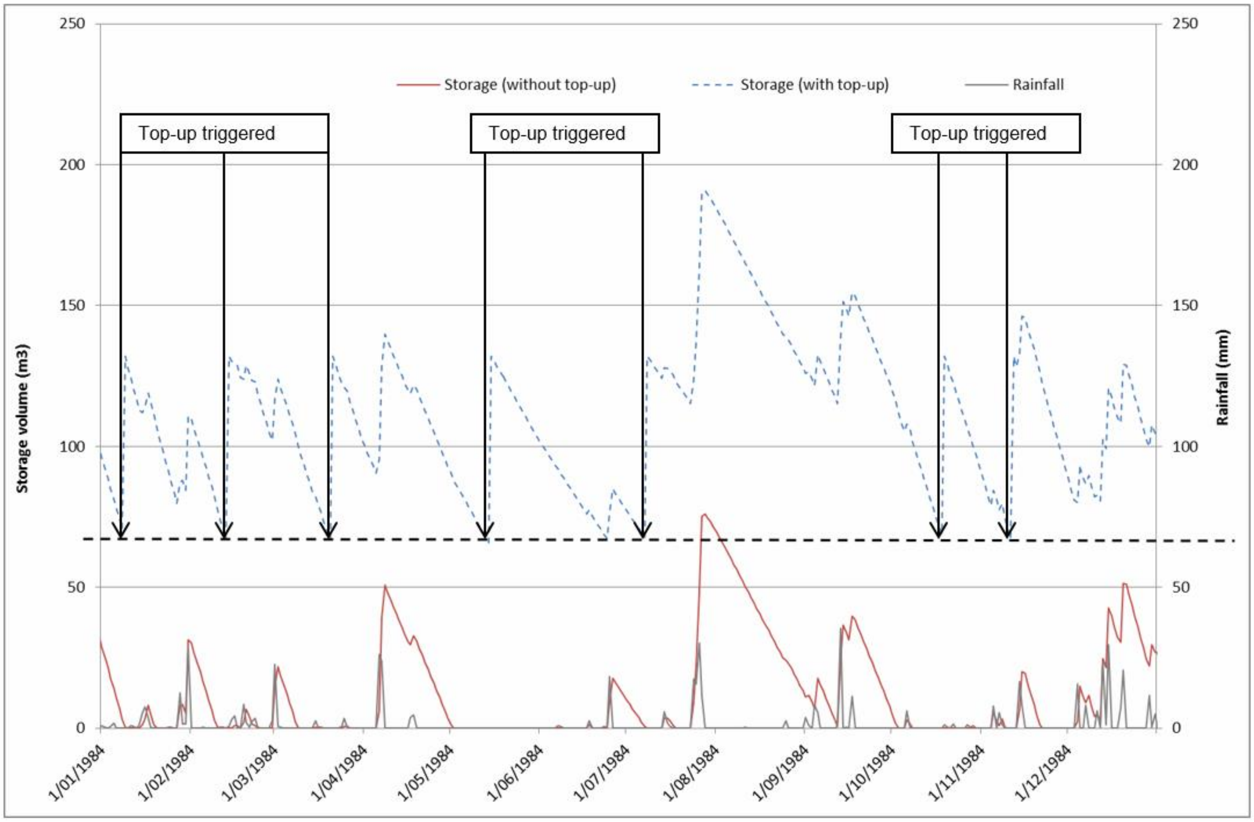

Figure 5. Storage volume comparison for wicking bed, with and with-out top up for one of the driest modelled years (annual rainfall 547 mm), highlighting how top-up helps to sustain storage volumes during dry years.

VII. Conclusion

This no-imported energy, low maintenance irrigation system will help sustain the lawn areas between rainfall events and will also increase the usability and resilience of this area after heavy rainfall events through improved sub-soil drainage.

The benefits of this novel, large scale application of wicking bed technology will be communicated to local and regional visitors through site tours as part of the parklands future Interpretive Centre services.

The potential of this scalable no-energy, stormwater harvesting technology is endless and its benefits wide-ranging. The benefits include:

Å Reduced stormwater and pollutant loads to the environment

Å Reduced potable water use

Å Reduced energy requirements for irrigation

Å Reduced fertiliser application

Å Retention of soil moisture

Å Increased turf resilience to dry periods

Å No water logging or boggy fields

Å Quick return to play following rainfall

Å Ease of maintenance and mowing

Å Deep root system and healthy turf

Å Supporting healthy lifestyles and active play

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