Stormwater harvesting storage management to achieve a sustainable landscape at Royal Botanic Gardens Victoria, Melbourne Gardens

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One of the most beautiful botanic garden landscapes in the world!
The Ornamental Lake Storage – A living system

**Constructed wetlands at Eastern end of Ornamental Lake**

*Working Wetlands Project*  
Wetlands – Ornamental Lake, RBG

**Floating treatment wetlands**  
(17 Beds. 1,000m²)

One month after pruning
Working Wetlands Project

Traditional Constructed Wetlands
(26 Nov 2011)

A-Gate Wetland
Floating Treatment Wetlands

Plant roots provide a very large surface area for nutrients to be absorbed.

A sticky biofilm (complex mass of micro-organisms) covering the roots helps trap fine particles and absorbs nutrients from the water.
Challenges for Melbourne Gardens Landscape

- Adapting to projected climate change
- Managing and securing sustainable water supplies
- Maintaining the value of a mature heritage landscape through the transition to a new climate
- Responding to biosecurity threats
## Climate change projections – Climate parameters

<table>
<thead>
<tr>
<th>Group</th>
<th>Parameter</th>
<th>Data Period</th>
<th>Baseline Data</th>
<th>2090 +/-</th>
<th>2090 Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Temp.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Annual Mean (°C)</td>
<td>1986-2005</td>
<td>15.9</td>
<td>+3.1</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Mean Days &gt;35 (°C)</td>
<td>1981-2010</td>
<td>11</td>
<td>+13</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Annual Mean Max.(°C)</td>
<td>1986-2005</td>
<td>20.4</td>
<td>+3.3</td>
<td>23.7</td>
</tr>
<tr>
<td></td>
<td><strong>Rainfall</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Annual Mean (mm)</td>
<td>1986-2005</td>
<td>624</td>
<td>-9%</td>
<td>574</td>
</tr>
<tr>
<td></td>
<td>Winter Mean (mm)</td>
<td>1986-2005</td>
<td>147</td>
<td>-10%</td>
<td>132</td>
</tr>
<tr>
<td></td>
<td>Spring Mean (mm)</td>
<td>1986-2005</td>
<td>180</td>
<td>-19%</td>
<td>146</td>
</tr>
</tbody>
</table>

Data sourced and adapted from Australian Bureau of Meteorology, and average values from a high emissions scenario (RCP 8.5) as indicated in projections from Grose M et al. (2015) *Southern Slopes Cluster Report, Climate Change in Australia Projections for Australia’s Natural Resource Management Regions: Cluster Reports*, eds. Ekström, M. et al., CSIRO and Bureau of Meteorology.
The *Landscape Succession Strategy* guides the transition from existing plantings to a composition more suited to projected climate and environment conditions of 2090.

**Question:**
Climate of Melbourne in 2090?

**Ans:** Dubbo, NSW
What is Landscape Succession?

Landscape succession is:

*The managed transition of a cultivated landscape from one state currently characterised by an existing palette of living plant collections to another state dominated by taxa more likely to be resilient to Melbourne’s projected climate.*
Living Collections under Current Climate Risk Scenario
Living Collections under Extreme Climate Risk Scenario

Legend

Grid Risk Levels
-6.0 - -5.6
-5.5 - -4.2
-4.1 - -2.8
-2.7 - -1.4
-1.3 - 0.0
0.1 - 1.4
1.5 - 2.8
2.9 - 4.2
4.3 - 5.6
5.7 - 7.0

Elm

Silver Birch
Outcomes

Climate Vulnerability Risk Assessment

Current
- Not considered vulnerable: 70%
- Low-moderate vulnerable: 18%
- Vulnerable: 12%

2070
- Not considered vulnerable: 33%
- Low-moderate vulnerable: 41%
- Vulnerable: 26%

Data Source: Kendal and Farrar 2017
The RBG Strategy has identified 5 Strategies and Targets

**Strategy 1:** Actively manage and transition the Melbourne Gardens landscape and plant collection

**Strategy 3:** Maximise sustainable water availability and use

**Target:** By 2020, 100% of landscape irrigation needs are provided by sustainable water sources.

*Ambitious*
Role of Ornamental Lake

a. Amenity
b. Ecological values (Closest ‘remnant’ freshwater body to CBD)
c. Recreation
d. Water treatment of harvested stormwater
e. Site water management – flood mitigation
f. Modify runoff to discharge – Yarra River
g. Irrigation and water banking storage
Lake Level- Amenity Value
Visitors and Tourists
Risks for the Lake storage

A. Depth of Lake
   - Amenity
   - Macrophyte health and function

B. Water quality
   - Nutrients
   - pH
   - EC
   - Toxins
   - Lack of oxygen

Need to consider: Physical, Chemical and Biological properties
Potential Water Level Conflict

1. Maximising yield for irrigation  (Large drawdown)
2. Protecting amenity value (Small drawdown allowed)
3. Protecting health of storage/ecosystem

Options:
- 300 mm Drawdown
- 500 mm Drawdown
Relative Water Levels 2002-2017

Ornamental Lake - Relative Water Levels 2002-17

Overflow/Capacity Level

Irrigation Draw-down Limit (60 cm RL)

Dates


Lake Level (cm AHD)

0.0 20.0 40.0 60.0 80.0 100.0 120.0 140.0 160.0

DRY!
Outbreak of *Azolla rubra* (Native, floating water fern)
Clean up cost is huge
- Labour hours (1,900 hrs) and $s

RBGV has now invested in an amphibious harvester.
$150 k

Macrophyte management
Oil spill- Local urban catchment
(Analysed as most similar to Emu oil !?, Source?)
Physico-chemical water quality parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Target Value</th>
<th>2012-17 Mean Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicarbonate</td>
<td>Mean mg/L</td>
<td>&lt;90</td>
<td>117.00</td>
</tr>
<tr>
<td>Boron</td>
<td>Mean mg/L</td>
<td>&lt;0.5</td>
<td>0.06</td>
</tr>
<tr>
<td>Chloride</td>
<td>Mean mg/L</td>
<td>&lt;40-100</td>
<td>84.00</td>
</tr>
<tr>
<td>Copper</td>
<td>Mean mg/L</td>
<td>&lt;0.2</td>
<td>0.01</td>
</tr>
<tr>
<td>Calcium</td>
<td>Mean mg/L</td>
<td>&gt;20&lt;100</td>
<td>23.60</td>
</tr>
<tr>
<td>Electrical Conductivity (EC)</td>
<td>dS/m</td>
<td>&lt;0.75</td>
<td>0.57</td>
</tr>
<tr>
<td>Iron</td>
<td>Mean mg/L</td>
<td>&lt;0.2-0.8</td>
<td>0.60</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mean mg/L</td>
<td>&lt;50</td>
<td>13.80</td>
</tr>
<tr>
<td>pH</td>
<td>Mean Unit</td>
<td>6-9</td>
<td>7.53</td>
</tr>
<tr>
<td>Sodium</td>
<td>Mean mg/L</td>
<td>&lt;50-100</td>
<td>55.30</td>
</tr>
<tr>
<td>Sodium Adsorption Ratio (SAR)</td>
<td>Mean Ratio</td>
<td>&lt;3</td>
<td>2.3</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Median NTU</td>
<td>&lt;25</td>
<td>5.0</td>
</tr>
<tr>
<td>Zinc</td>
<td>Mean mg/L</td>
<td>&lt;2</td>
<td>0.06</td>
</tr>
</tbody>
</table>
Cyanobacteria (Blue-green algae counts for Ornamental Lake)

<table>
<thead>
<tr>
<th>Period</th>
<th>All Cyanobacteria spp. (Median cells/100 ml)</th>
<th>Dolichospermum spp. (Median cells/ml)</th>
<th>Microcystis spp. (Median cells/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996-2012</td>
<td>5793</td>
<td>4580</td>
<td>2300</td>
</tr>
<tr>
<td>2011-12</td>
<td>4203</td>
<td>5807</td>
<td>29587</td>
</tr>
<tr>
<td>2012-13</td>
<td>5879</td>
<td>1975</td>
<td>2643</td>
</tr>
<tr>
<td>2013-14</td>
<td>887</td>
<td>3088</td>
<td>119</td>
</tr>
<tr>
<td>2014-15</td>
<td>5793</td>
<td>2401</td>
<td>1058</td>
</tr>
<tr>
<td>2015-16</td>
<td>233</td>
<td>211</td>
<td>17</td>
</tr>
<tr>
<td>2016-17</td>
<td>250</td>
<td>17</td>
<td>52</td>
</tr>
</tbody>
</table>

Main cyano. reductions from 2015-2016 – Combination of reducing detention time (recirculation), reduction in nutrient loadings and competition from macrophytes (probably strongest influence).
Phosphorous levels (mg/L)

Compared to 2002-2012 baseline—bioavailable phosphorous levels are 91% less for 2016-17. These are the lowest levels recorded so far.
Mean ammonia and Nox levels

Compared to 2002-2012 baseline—bioavailable nitrogen levels were over 85% less for 2016-17. These are the lowest levels recorded thus far.

Nutrient reduction a major achievement!
### Treatment results for E.coli levels in Lake

<table>
<thead>
<tr>
<th>Period</th>
<th>Pre-treatment Median (CFU/100 ml)</th>
<th>Post-UV treatment Median (CFU/100 ml)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>31/10/12 to 20/02/14</td>
<td>280</td>
<td>2.5</td>
<td>20 samples</td>
</tr>
<tr>
<td>31/10/12 to 7/06/17</td>
<td>240</td>
<td>1</td>
<td>35 samples</td>
</tr>
</tbody>
</table>
Water Balance

- Inflow
- Evaporation Losses
- Seepage Losses
- Outflow

Outflow:
1. Irrigation
2. Soil water banking
3. Discharge
# Modelled Demand and Storage Summary

<table>
<thead>
<tr>
<th>Item</th>
<th>(ML/Year)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total stormwater yield</td>
<td>76</td>
<td>Modelled on assumed climatic conditions for 1999-2008 (528 mm rainfall; 1185 mm pan evaporation)</td>
</tr>
<tr>
<td>Evaporation</td>
<td>21</td>
<td>Excludes water use by aquatic plants and marginal vegetation (ET), and seepage losses</td>
</tr>
<tr>
<td>Potential Lake overflow</td>
<td>14</td>
<td>If not harvested for Soil Moisture Storage and Recovery (SMSR)</td>
</tr>
<tr>
<td>Total available for irrigation with no management intervention</td>
<td>41</td>
<td>If SMSR is not applied</td>
</tr>
<tr>
<td>Total available for irrigation with storage and demand management</td>
<td>55</td>
<td>Includes Lake overflow as SMSR (banked)</td>
</tr>
</tbody>
</table>
## Actual Water Balance Estimation

<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Annual Rainfall (mm)</td>
<td>506</td>
<td>596</td>
<td>464</td>
<td>431</td>
<td>550</td>
<td>490</td>
</tr>
<tr>
<td>Ornamental Lake Inflows (ML)</td>
<td>57.4</td>
<td>73.0</td>
<td>49.0</td>
<td>42.2</td>
<td>67.0</td>
<td>56.0</td>
</tr>
<tr>
<td>Total Losses (ML)</td>
<td>-53.2</td>
<td>-61.1</td>
<td>-37.8</td>
<td>-50.4</td>
<td>-68.2</td>
<td>-48.4</td>
</tr>
<tr>
<td>Irrigation Use (ML)</td>
<td>-32.0</td>
<td>-48.3</td>
<td>-15.0</td>
<td>-31.3</td>
<td>-46.6</td>
<td>-18.6</td>
</tr>
<tr>
<td>Evaporation/ Leakage/ Overflow (ML)</td>
<td>-19.7</td>
<td>-12.8</td>
<td>-22.8</td>
<td>-20.1</td>
<td>-13.2</td>
<td>-29.8</td>
</tr>
</tbody>
</table>

When annual rainfall is similar to modelled/design baseline, then expected harvest volumes are achieved.

Note: Evaporation losses are likely underestimated, some overflows are not able to be measured.
Aggregate of Rainfall and Irrigation

Melbourne Gardens
Aggregate of Rainfall and Irrigation

Total water needs of plants
Irrigation Water Source

Mainly potable!
Water banking opportunity - Relative water levels 2016/2017

Ornamental Lake - Relative Water Levels 2016-17

Overflow/Capacity Level

Irrigation Draw-down Limit (60 cm RL)

Lake Level (cm AHD)

Dates

20-Jan-16  12-Sep-16  1-Dec-16  1-Jul-17  4-Jul-17
Water banking - Subsoil Moisture Storage and Recovery

Potential available water storage
= 557 mm or 155 ML over 27.8 Ha

Research partnership with University Melbourne
and Sentek Technologies

2 Probes to 4 m
4 Probes to 2 m
Site water management requires knowing irrigation demand.

Typical Landscape Coefficients ($K_L$) used in summer at RBG Melbourne:

- $K_L 0.4$
- $K_L 0.6-0.7$
- $<K_L 0.3$
- $K_L 0.5$
Lake Storage Management Lessons

1. Continual monitoring of Lake level for opportunities to export to soil banking.

2. The Lake and wetlands as a treatment system works.
   Nutrient reductions are evidence of this.

3. Water body/column conditions can favour unwanted macrophyte (Azolla) growth.
   Better understanding of Lake environment conditions and growth habitat of Azolla.
Lake Storage Management Lessons

4. Diligent monitoring of the natural and synthetic systems is essential.
   Accurate and reliable Instrumentation/sensing – Quality; Maintenance;
   Certification; Calibration

5. Urban catchment risks.
   Prevention techniques. Who is the responsible authority?

effectiveness
Lake Management Strategies

1) Maximise beneficial use of harvested water – Minimise discharge to Yarra

2) Use water for irrigation efficiently

3) Maximise soil water banking

4) Achieve effective water treatment

5) Maintain suitable Lake levels for other functional use
   E.g. Revenue raising for RBGV through punting activities