Reliability of water supply from stormwater harvesting and managed aquifer recharge with a brackish aquifer in an urbanising catchment and changing climate

R. Clark a, D. Gonzalez b, c, P. Dillon b, S. Charles c, D. Cresswell a, B. Naumann d

a Clark and Associates, Adelaide, Australia
b CSIRO Land and Water, PB2 Glen Osmond, SA 5064, Australia
c CSIRO Land and Water, PMB Wembley, WA 6014, Australia
d City of Salisbury, PO Box 8, Salisbury, SA 5108, Australia

Presenter: Dennis Gonzalez
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- City of Salisbury
- Adelaide and Mt Lofty Ranges Natural Resources Management Board
- University of Adelaide
- University of South Australia
- South Australian Water Corporation
- United Water International/Allwater
Background

• MARSUO focus on water quality & risk management
• Key knowledge gap: volumetric reliability of supply
• Parafield stormwater harvesting and MAR case study site
• Modified WaterCress hydrological model used for simulations
Aims and linkages

• What would be the impacts of
  1. Changing climate
  2. Increased urbanisation
  3. Surface detention time
  4. Recharge rate
  5. Aquifer storage depreciation
  6. Minimum aquifer storage volume
• Downscaled climate data (Goyder – Enviro Data SA)
• ‘Top down’ vs ‘bottom up’ & current climate resilience
  Goyder project
WaterCress model structure

<table>
<thead>
<tr>
<th>Sub-catchment</th>
<th>Ha</th>
<th>Impervious</th>
<th>Pervious</th>
<th>Rainfall scaling factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>121</td>
<td>3%</td>
<td>97%</td>
<td>1.05</td>
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<tr>
<td>2</td>
<td>118</td>
<td>58%</td>
<td>42%</td>
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<td>64%</td>
<td>1.01</td>
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<td>113</td>
<td>45%</td>
<td>55%</td>
<td>1.01</td>
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<td>49</td>
<td>48%</td>
<td>52%</td>
<td>1.08</td>
</tr>
<tr>
<td>6</td>
<td>46</td>
<td>55%</td>
<td>45%</td>
<td>1.08</td>
</tr>
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<td>7</td>
<td>67</td>
<td>14%</td>
<td>86%</td>
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<td>1.03</td>
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<td>47%</td>
<td>53%</td>
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<tr>
<td>10</td>
<td>77</td>
<td>28%</td>
<td>72%</td>
<td>1.05</td>
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<td>11</td>
<td>119</td>
<td>42%</td>
<td>58%</td>
<td>1.05</td>
</tr>
<tr>
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<tr>
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<td>54%</td>
<td>1.01</td>
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<tr>
<td>14</td>
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<td>34%</td>
<td>66%</td>
<td>1.00</td>
</tr>
<tr>
<td>15</td>
<td>72</td>
<td>45%</td>
<td>55%</td>
<td>1.00</td>
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<tr>
<td>Total</td>
<td>1592</td>
<td>37%</td>
<td>63%</td>
<td>1.03</td>
</tr>
</tbody>
</table>

Node Type
- pervious
- impervious (residential)
- impervious (industrial)
- routing
- diversion weir
- surface storage
- aquifer storage
- customer demand
- Rain Gauge
- PDS Flow Gauge
- ASR Wells
- Model Flow
- Sub-catchment
- Wetland

Parafield Stormwater Harvesting Facility
## Modelling scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Base case</th>
<th>Climate change</th>
<th>Surface detention time</th>
<th>Recharge rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall sequence</td>
<td>Historical</td>
<td>GFDL ESM (2M)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean annual rainfall (mm)</td>
<td>460</td>
<td>428 (-7%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface detention</td>
<td>3 days</td>
<td>10 days (+333%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injection rate (L/s)</td>
<td>90 (4 x 22.5)</td>
<td></td>
<td></td>
<td>68 (-24%)</td>
</tr>
</tbody>
</table>
Rainfall sequences

- Two representations of synthetic rainfall sequences
  1. Representative of historical rainfall (1959-2009)
  2. Representative of a drying climate in southern Australia (2010-2060); high emissions pathway RCP of 8.5 W/m² by the year 2100
- 100 iterations of 51 years of daily rainfall for each rainfall sequence (Parafield Airport BOM station)
## Climate data summary

<table>
<thead>
<tr>
<th>Rainfall record</th>
<th>Mean Rainfall (mm)</th>
<th>Mean No. Rain Days (&gt;1mm)</th>
<th>1 in 1 year ARI (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual (1972-2009)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Annual</td>
<td>Summer</td>
<td>Autumn</td>
</tr>
<tr>
<td></td>
<td>438</td>
<td>57</td>
<td>104</td>
</tr>
<tr>
<td>1A simulated (1959-2009)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>446</td>
<td>61</td>
<td>116</td>
</tr>
<tr>
<td>1B Climate change (2010-2060)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>415</td>
<td>59</td>
<td>106</td>
</tr>
<tr>
<td>Difference between 1A &amp; 1B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7%</td>
<td>3%</td>
<td>9%</td>
</tr>
</tbody>
</table>
Rainfall-runoff modelling

- Total catchment imperviousness 38%
- Rainfall-runoff modelling in WaterCress
  - Linear component (impervious surfaces) conforms to Australian Rainfall Runoff method (Engineers Australia, 2014)
  - Non-linear component (pervious surfaces) used a version of Australian Water Balance Model (Boughton, 2004)
Rainfall-runoff calibration

- 6 years of flow gauge data from Parafield Drain Station near harvesting point
- Initial loss & connectivity parameters adjusted to minimise RMSE
- Minor curvature evident in correlation, component calibrated separately using AWBM (non-linear)
- Monthly total flow & rainfall significant linear correlation

![Graph showing monthly modelled flow vs. monthly gauged flow with R² = 0.95]
Aquifer freshwater storage depreciation

• Mixing losses through storage in brackish aquifer

• Single parameter storage depreciation rate model - imagine a leaky bucket

• Depreciation rate constant calibrated against recovered water salinity to result in effective freshwater storages close to zero at times of observed salinity spikes

• Rate of 0.04% volumetric storage loss per day
Aquifer freshwater storage depreciation

Volume (ML), TDS (mg/L)

- $S_i$
- $rS_i$
- TDS ASR 1
- TDS ASR 2

Jan-03 to Jan-14
Aquifer freshwater storage depreciation

- Freshwater storage ($fS_i$) versus high TDS (>400 mg/L) strong correlation
- When $fS_i = 0$ trigger for ceasing supply

![Graph showing correlation between TDS and storage volume]
Demand & supply reliability

- Historical annual demand pattern of **30% uniform** (industry use), **70% seasonal** (irrigation)

- Seasonal demand pattern determined by monthly rainfall and evaporation and public open space irrigation requirements for South Australia (SA Water, 2010)

- Mean annual volumetric supply reliability defined as volume supplied as percentage of total demand from 51 years x 100 simulations

- Range of demands run to determine 95 to 99.5% mean annual volumetric supply reliability for scenarios
The model working
Supply reliability curves
# Hydrological summary

Mean annual hydrological summary statistics for modelled scenarios with volumetric supply reliability of 99.5%

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Rainfall (mm)</th>
<th>Runoff (ML)</th>
<th>Recharge (ML)</th>
<th>Supply (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base case</td>
<td>460</td>
<td>1287</td>
<td>1067</td>
<td>937</td>
</tr>
<tr>
<td>Climate change</td>
<td>428</td>
<td>1209</td>
<td>1011</td>
<td>901</td>
</tr>
<tr>
<td>Increased surface storage time (+7 days)</td>
<td>460</td>
<td>-</td>
<td>938</td>
<td>827</td>
</tr>
<tr>
<td>Reduced injection rate (-24%)</td>
<td>460</td>
<td>-</td>
<td>1051</td>
<td>909</td>
</tr>
</tbody>
</table>

* Difference compared to base case
Conclusions

• Generic modelling approach for planning & design of stormwater MAR systems & increasing investor confidence

• Simple method accounting for storage depletion calibrated on 10 years operational data

• 7% less rainfall under climate change led to 6% less runoff, 5% less recharge and 3% less supply

• Runoff from pervious reservoir and river catchments expected to drop by 2-3 times more than proportional rainfall decline under climate change (Dillon, 2011; Cai and Cowan, 2008)

• Surface storage time is sensitive, indicates bottle-neck

• Current Goyder climate project to test sensitivity of hydroclimatic variables on similar model – *bottom up meets top down*
Thank you

Dennis Gonzalez
CSIRO Land & Water

t +61 8 8303 8745
e dennis.gonzalez@csiro.au
w www.csiro.au
References


