Towards the Quantification of Rainwater Tank Yield in South East Queensland by Considering the Spatial Variability of Tanks

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TALK OUTLINE

• Outline
  – Project background
  – Developing a method to quantify rainwater tank yield at the SEQ scale
  – Results
  – Conclusions
Use of household rainwater tanks

- Capital cities: 15% in 2007 and 26% in 2010
- Queensland: 18% in 2007 and 43% in 2010 (largest increase of all cities)
- 70 kL/year mandatory water savings target for all new houses in Qld
- Internally plumbed RWTs contribute to achieving this target

Source: ABS, March 2010
Yield of household rainwater tanks

- As the uptake of tanks increases, there is a need for quantifying the yield at the SEQ scale
  - To assess SEQ’s supply and demand balance
- Common practice is linear up-scaling of the yield of a tank with average tank characteristics
  - Can introduce errors because tank yield is not linearly related to tank characteristics

Source: SEQ Water Strategy, 2010
Variability exhibited by rainwater tanks in SEQ

- Beal *et al.* (2012) study based on 2008 water consumption data
  - 20 kL/h/y to 95 kL/h/y, with a mean of 50 kL/h/y

- Chong *et al.* (2011) study based on 2009 and 2010 consumption data
  - 24.5 kL/h/y to 88.5 kL/h/y, with a mean of 58.8 kL/h/y
Objectives of the study

• To develop a method to account for the spatial variability of supply from rainwater tanks, for the prediction of potable water savings at the SEQ scale.

• To understand the extent of error caused to tank yield by ignoring the spatial variability.
The method: Monte Carlo simulation of rainwater tank yield

Probabilistic representation of residential end uses; improvements made to Duncan and Mitchell (2008) method

Probability distributions to represent spatial variability of tank sizes, effective roof area and roof losses; improvements made to Mitchell et al. (2008) rainwater tank model
Spatial variability exhibited by the input data

- Household water consumption in Brisbane (61 SFR households): 30 - 650 L/p/d
- Connected roof area (20 houses in SEQ): 37 – 135 m²
- Tank sizes (106 tanks in Brisbane): 4 – 22 kL
## Monte Carlo Simulation: input variables (tank)

<table>
<thead>
<tr>
<th>Units</th>
<th>Tank size</th>
<th>Effective roof area</th>
<th>Initial loss</th>
<th>Continuing loss</th>
<th>Occupancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>2.5 kL</td>
<td>27.0 m²</td>
<td>0 mm</td>
<td>0 %</td>
<td>1 No.</td>
</tr>
<tr>
<td>Mean</td>
<td>5.1 kL</td>
<td>76.6 m²</td>
<td>0.5 mm</td>
<td>15 %</td>
<td>2.6 No.</td>
</tr>
<tr>
<td>Maximum</td>
<td>25.0 kL</td>
<td>135.0 m²</td>
<td>1.8 mm</td>
<td>30 %</td>
<td>6 No.</td>
</tr>
<tr>
<td>Probability distribution</td>
<td>Truncated Normal</td>
<td>Truncated Normal</td>
<td>Truncated Normal</td>
<td>Truncated Normal</td>
<td></td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.1 kL</td>
<td>28.8 m²</td>
<td>0.5 mm</td>
<td>5 %</td>
<td></td>
</tr>
<tr>
<td>Sample size</td>
<td>106</td>
<td>20</td>
<td>Unknown (literature based)</td>
<td>Unknown (literature based)</td>
<td>61</td>
</tr>
</tbody>
</table>
Monte Carlo Simulation: input variables (demand)

- Sampling from 200 plausible demand time series
  - Generated by calibrating the Stochastic Demand Model of Duncan and Mitchell (2008) using 61 household end use demands in Brisbane

- Tank water is used for toilet, laundry and garden use
  - About 50% of the total household use

### Per capita observed end use break down - Brisbane

- Toilet: 22.0 L/p/d (17%)
- Clothes Washer: 15.8 L/p/d (27%)
- Tap: 22.7 L/p/d (17%)
- Dishwasher: 2.3 L/p/d (2%)
- Shower: 38.6 L/p/d (30%)
- Irrigation: 7.2 L/p/d (6%)

Total average = 130.4 L/p/d

### Per capita modelled end use break down - Brisbane

- Toilet: 20.3 L/p/d (15%)
- Clothes Washer: 18.0 L/p/d (29%)
- Tap: 27.4 L/p/d (20%)
- Dishwasher: 2.3 L/p/d (2%)
- Shower: 38.4 L/p/d (25%)
- Irrigation: 5.7 L/p/d (4%)  

Total average = 134.1 L/p/d
Tank yield for different iterations of Monte Carlo simulation
Monte Carlo simulation on a daily time step

Average annual yield of 10,000 houses over 50 year (1960-2010) daily simulation

47 kL/h/y (14% overestimation) 41 kL/h/y
Monte Carlo simulation on an hourly time step

Average annual yield of 10,000 houses over 50 year (1960-2010) hourly simulation

46 kL/h/y (14% overestimation)

40 kL/h/y
Comparison with yield estimated from billing data

- QWC study: Billing records of 1841 single family residential houses in Brisbane during the period from January 2011 to June 2011
  - The sample had 120 houses with internally plumbed rainwater tanks (IPR) and 1721 SFR houses without IPR
  - Compared the average household consumption of the two samples
  - The estimated average yield: 39 L/p/d or 37 kL/h/y (considering an occupancy rate of 2.6 p/h)

- Our study (stochastic simulation): 40 kL/h/y
Conclusions

- Tank sizes, connected roof areas and household end uses vary spatially.
- We examined the effectiveness of Monte Carlo simulation of tank storage behaviour to represent this variability.
- Tank yield quantified through Monte Carlo simulation is 40 kL/h/y. This is about 30% of total household use in Brisbane.
- If the spatial variability of tank and water use characteristics are ignored, the tank yield will be overestimated by 14% (for Brisbane household data).
- Work in progress to repeat the analysis for Gold Coast, Sunshine Coast and Ipswich.
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THANK YOU!

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