Comparing Actual and Designed Water Demand in Australian Multi-level Residential Buildings

A collaboration between Deakin University, HCAA and ABCB
Presentation Structure

• Introductions
• Interactive Survey
• Work completed to date:
  • HCAA Water Demand Investigation
  • Hydraulic Modelling
• Implications
• Recommendations For Future Work
• Interactive Discussion
• Questions
Introduction

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ABCB: Student Scholarship Program
What are the **top three limitations** of current plumbing standards and practices for cold and heated water systems (in words or short phases)?

Go to [www.menti.com](http://www.menti.com)
A project commissioned by the Hydraulic Consultants Association of Australasia (HCAA) after:

“An unofficial investigation carried out in 2018 on a 13 stories high residential building with around 120 apartments confirmed what most professionals in our industry suspected:

“The methods for sizing pipes is significantly outdated and as a result, they are often oversized.”

The project set out to be able to reduce:

- *Risk to public health by ensuring self cleansing velocities in pipework.*
- *Valuable retail space required for hydraulic services.*
- *The embodied energy of hydraulic service components.*
- *Capital and ongoing costs for the building owner.*
- *The carbon footprint of hydraulic systems.*

HCAA is currently monitoring the water usage in four buildings:

1) Waterloo, NSW – 145 Apartments (Residential)
2) Milsons Point, NSW – 123 Apartments (Residential)
3) Manhattan, ACT – 330 Apartments (Residential)
4) Braddon, ACT – 115 Apartments (Mixed use)

Future - Extend monitoring to other building types:

• Hospitals
• Aged Care
• Offices
• Schools
• Commercial Buildings
# HCAA Water Demand Investigation

## Buildings

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Monitoring Period</th>
<th>Estimated Occupancy</th>
<th>Design Peak Flow (AS/NZS 3500.1)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site 1: Waterloo, Sydney, NSW</strong></td>
<td>Monitoring Dates: 13&lt;sup&gt;th&lt;/sup&gt;-Aug-19 to 14&lt;sup&gt;th&lt;/sup&gt;-Mar-20</td>
<td>Estimated Occupancy: 90%</td>
<td>9.74L/s</td>
</tr>
<tr>
<td><strong>Site 2: Milsons Point, Sydney, NSW</strong></td>
<td>Monitoring Dates: 17&lt;sup&gt;th&lt;/sup&gt;-Oct-19 to 14&lt;sup&gt;th&lt;/sup&gt;-Mar-20</td>
<td>Estimated Occupancy: 90%</td>
<td>8.74L/s</td>
</tr>
<tr>
<td><strong>Site 3: Manhattan, Canberra, ACT</strong></td>
<td>Monitoring Dates: 14&lt;sup&gt;th&lt;/sup&gt;-Dec-19 to 14&lt;sup&gt;th&lt;/sup&gt;-Mar-20</td>
<td>Estimated Occupancy: 95% (15% of apartments are 'short term')</td>
<td>18.2L/s</td>
</tr>
<tr>
<td><strong>Site 4: Braddon, Canberra, ACT</strong></td>
<td>Monitoring Dates: 17&lt;sup&gt;th&lt;/sup&gt;-Jan-20 to 14&lt;sup&gt;th&lt;/sup&gt;-Mar-20</td>
<td>Estimated Occupancy: Unknown</td>
<td>8.33L/s</td>
</tr>
</tbody>
</table>

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<td>Estimated Occupancy: Unknown</td>
<td>Design Peak Flow (AS/NZS 3500.1)</td>
<td></td>
</tr>
</tbody>
</table>

### Notes:

- **a** Total apartment count excludes common space.
- **b** Total apartment count excludes gym.
- **c** Total apartment count excludes ground floor and level 1.
HCAA Water Demand Investigation

Method

- Flexus F501 ultrasonic flow meter & i20 data logger fitted to main cold water pipe.

- Flow rate acquisition level set to 5 second intervals.
- Flow rate logging set 1-minute average value of 5-second acquisitions and sent to cloud via GSM network.

- Recorded values downloaded as csv.
- Marcos written to arrange data into daily usage patterns for analysis.

Water consumption data was analysed for:

- Peak flow rate.
- Flow rate frequencies.
- Comparison against Australian and comparable international plumbing codes:
  - IAPMO’s Water Demand Calculator (https://www.iapmo.org/water-demand-calculator/).
  - Verification Method (under investigation by the ABCB)
Limitations are associated to the logging frequency of flow rate data at 1-minute intervals:

- Limited in capturing short fixture usage events < 30-seconds, i.e. taps, toilets.
- A correction value of 1.3 was applied to absolute maximum of recorded flow rates (derived from similar research).

![Individual Fixture Usage](image)

**Example of individual fixture usages compared with total water demand, 5-second acquisitions and 1-minute logging frequency.**
### HCAA Water Demand Investigation

#### Results: Peak Flow Rates

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Waterloo, NSW [215]</td>
<td>143</td>
<td>1291</td>
<td>2.3</td>
<td>2.76</td>
<td>1.65</td>
<td>9.74</td>
<td>2.88</td>
<td>2.13</td>
<td>6.01</td>
<td>326%</td>
</tr>
<tr>
<td>2 Milsons Point, NSW [149]</td>
<td>123</td>
<td>1223</td>
<td>3.1</td>
<td>3.75</td>
<td>1.85</td>
<td>8.74</td>
<td>2.84</td>
<td>2.10</td>
<td>5.96</td>
<td>217%</td>
</tr>
<tr>
<td>3 Manhattan, ACT [92]</td>
<td>330</td>
<td>2912</td>
<td>4.6</td>
<td>5.52</td>
<td>3.75</td>
<td>18.2</td>
<td>3.52</td>
<td>3.59</td>
<td>12.3</td>
<td>304%</td>
</tr>
<tr>
<td>4 Braddon, ACT [58]</td>
<td>115</td>
<td>859</td>
<td>2.35</td>
<td>2.82</td>
<td>1.50</td>
<td>8.33</td>
<td>2.62</td>
<td>1.76</td>
<td>4.35</td>
<td>273%</td>
</tr>
</tbody>
</table>

**Notes:**

- Corrected value assume 1.3 of measured values.
- Assumes 99th percentile flow within peak hour of water consumption for all monitoring days.
- Percentage calculated using corrected values.

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**Graph:**

- Measured
- Corrected (multiplied by a factor of 1.3)
- AS/NZS 3500.1:2018
- DIN 2012
- IAPMO WDC
- ABCB VM

**Text:**

"Assuming corrected peak flow rate values: AS/NZS 3500.1:2018 overestimates peak flow rates between 217%-326."
Flow rate data was arranged into clusters of 0.1L/s
Chart demonstrates range and frequency each building spent at specific flow rate during monitoring.

• Peak conditions are rare!
• For sites 1, 2, & 4 - buildings spent 90% of time operating at less than 1.0L/s. (Max’ = 2.3-3.1L/s)
• For site 3 – 90% of flow rates were less than 2.0L/s (Max’=4.6L/s)
• Assuming an allowable pipe flow velocity of 1.5-2.1m/s:
  • Sites 1, 2 & 4 could be resized from DN100 to DN40.
  • Site 3 could be resized from DN100 to DN50.

Cumulative distribution of flow rates observed in monitored buildings, shown against alternative pipes sizes assuming 1.5m/s flow velocity (e.g. 1.5L/s flow will result in ~1.5m/s velocity in DN40 copper pipes)
Hydraulic modelling was performed to:

1) Gain a deeper understanding of hydraulic conditions present in current cold-water service networks. (Current State)

2) Consider the impacts of a reduced system size. (Future State)
A hydraulic model of the Waterloo building (site 1) cold-water service network was built in Bentley openflows WaterGEMS.

Modelling considered four ‘steady-state’ scenarios:
Modelled cold-water service includes:

- 1 pumping station (3 VSD pumps in parallel).
- 981 copper pipe elements (DN20 to DN100).
- 34 PLV, 1 PRV, 1 RPZD.
- 145 20mm water meters.
- 2 heated water storage units.
Single period scenarios considered flow rate in all pipes.

- Large gap between design (AS/NZS 3500.1) and measured flow rates.

Extended period (3hr) scenarios measure the flow rate of the main cold-water service and the base of risers for towers A, B and C.

- Zero flow was common.
- Highly varied flow rates.

Hydraulic Modelling

Results: Flow Rates

Cumulative frequency plot of pipe flow rates for AS/NZS 3500.1 and monitored single period hydraulic modelling scenarios

Flow rates experienced in main cold-water, riser A, riser B and riser C pipes during extended period hydraulic modelling

Main Cold-water Peak = 2.92L/s

Riser ‘A’ Peak = 0.87L/s

Riser ‘B’ Peak = 1.58L/s

Riser ‘C’ Peak = 1.66L/s
Single period scenarios:
- AS/NZS 3500.1 peak velocity = 1.2m/s.
- Monitored = 0.5m/s.

Extended period scenarios:

<table>
<thead>
<tr>
<th>Description</th>
<th>Monitored</th>
<th>Resized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe size: Main Cold-water</td>
<td>DN100</td>
<td>DN40</td>
</tr>
<tr>
<td>Maximum flow: Riser A (demand)</td>
<td>2.92L/s</td>
<td>2.92L/s</td>
</tr>
<tr>
<td>Pipe flow velocity: Cold-water main</td>
<td>0.38m/s</td>
<td>2.92m/s</td>
</tr>
<tr>
<td>Pipe size: Riser A</td>
<td>DN65</td>
<td>DN25</td>
</tr>
<tr>
<td>Maximum flow: Riser A (demand)</td>
<td>0.87L/s</td>
<td>0.87L/s</td>
</tr>
<tr>
<td>Pipe flow velocity: Riser A</td>
<td>0.30m/s</td>
<td>2.10m/s</td>
</tr>
<tr>
<td>Pipe size: Riser B</td>
<td>DN80</td>
<td>DN32</td>
</tr>
<tr>
<td>Maximum flow: Riser B (demand)</td>
<td>1.58L/s</td>
<td>1.58L/s</td>
</tr>
<tr>
<td>Pipe flow velocity: Riser B</td>
<td>0.38m/s</td>
<td>2.34m/s</td>
</tr>
<tr>
<td>Pipe size: Riser C</td>
<td>DN80</td>
<td>DN32</td>
</tr>
<tr>
<td>Maximum flow: Riser B (demand)</td>
<td>1.66L/s</td>
<td>1.66L/s</td>
</tr>
<tr>
<td>Pipe flow velocity: Riser C</td>
<td>0.40m/s</td>
<td>2.46m/s</td>
</tr>
</tbody>
</table>

Flow never reaches self-cleansing velocity of 0.5m/s.

Flow rate velocities experienced in main cold-water, riser A, riser B and riser C pipes during extended period hydraulic modelling with recommended (1.5m/s) and design (3m/s) velocity limits.
Pump parameters were set to achieve 250kPa at most hydraulically disadvantaged apartment node (level 10, tower ‘C’).

Single period scenarios showed little difference at the pumpset:

- AS/NZS 3500.1 = 30.27m head
- Flow rate = 4.88L/s
- Operating Efficiency = 69.6%
- Monitored = 27.47m head
- Flow rate = 2.84L/s
- Operating efficiency = 66.52%
As built system = minimal variation

*Monitored (extended period) results*
- Pressure = 25.63 – 27.48m head
- Average Operating Efficiency = 20.0%

Re-sized system = significant variation

*(High head loss at peak flows)*

*Re-sized (extended period) results*
- Pressure = 27.15 – 64.89m head
- Average Operating Efficiency = 25.8% (lead pump)
- Resizing pumps did little to improve operating efficiency (varied flows)

"Average flow rate of 3-hour period was 0.48L/s."
Hydraulic Modelling
Results: Plumbing hardware – Extended Period

Plumbing devices are designed to operate within a specified flow velocity range.

PRV recommended flow velocity range = 1.0-2.0 m/s.

As Built system
• Velocity range = 0-0.4 m/s

Re-sized system
• Velocity range = 0-2.35 m/s
• PRV spent less than 20% of time at 1.0-2.0 m/s

Mains cold-water PRV (DN100) flow velocity observed:
Monitored extended period scenario

Mains cold-water PRV (DN40) flow velocity observed:
Re-sized extended period scenario
Peak flow over-estimation promote the design of over-sized systems resulting in low flows that leads to:

- Increased construction costs.
- Elevated energy consumption and CO2 emissions
- Reduced water quality due to low flow rates.

Source: https://www.cdc.gov/legionella/wmp/overview/growth-and-spread.html
Simply reducing the pipe size may bring other problems!

- Higher velocity
  - Erosion-corrosion
- Wider range of flow conditions
  - High energy consumption and CO2 emission
- Water hammer
  - Noise and premature failure

Water-related energy use accounts for
- 13% (VIC) and 79% (QLD) of total household energy use
- 6% to 25% of total household energy-related GHG emissions

Binks et al. (2016)

Future standards and practices should address the life-cycle performance of the plumbing system.

R&D Topics:
• More accurate peak demand estimation for various types of buildings
• Performance-based design solutions
• Minimising full life-cycle cost
• Improving energy efficiency and reducing CO2 emission
• Preventing water hammer and premature failure
With the support of the HCAA, Deakin University has undertaken a PhD project with the focus of Improving Design Standards of Premise Plumbing Systems.

We welcome any industry insight on where to focus our research efforts!

Go to www.menti.com
• Please help to determine the level of importance of the five R&D topics.

Type in the chat box
• Are there other R&D topics need to be considered?
• What support the industry is willing to provide?
Questions?

All findings presented will be published in a report commissioned by the ABCB and its Student Scholarships Program in the coming weeks.

Any further questions? Please don’t hesitate to get in contact:

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Brendan Josey – email: bjosey@deakin.edu.au