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

Dr James Gong

Lecturer

School of Engineering

Deakin University

Email: james.gong@deakin.edu.au

Expertise: Smart Water System Design & Analytics / Pipeline Condition Monitoring

Brendan Josey

PhD Student

School of Engineering

Deakin University

Email: bjosey@deakin.edu.au

PhD focus: Improving Design Standards of Premise Plumbing Systems

Supporting Bodies

HCAA: Water Demand Investigation

Email: nick.soden@hcaa.org.au

ABCB: Student Scholarship Program

https://www.abcb.gov.au/ABCB/Scholarship

Survey

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**

HCAA Water Demand Investigation

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"The methods for sizing pipes is significantly outdated and as a result, they are often oversized."

https://www.waterdemand.com.au/

HCAA Water Demand Investigation

Project Goals

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.*

Source: https://www.waterdemand.com.au

HCAA Water Demand Investigation

Buildings

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

Site Location Monitoring Period Estimated Occupancy	Bedrooms	Bathrooms	Kitchen Sink	Dishwasher	Laundry Tub	Washing Machine	Shower	Basin	Toilet	Bath	Urinal	Apartments	Total Apartments	Total Fixtures	Design Peak Flow (AS/NZS 3500.1)
Site 1: Waterloo, Sydney, NSW Monitoring Dates: 13th-Aug-19 to 14th-Mar-20 Estimated Occupancy: 90%	252	239	145	143	143	143	239	239	239	-	-	145	[a]143	1291	9.74L/s
Site 2: Milsons Point, Sydney, NSW Monitoring Dates: 17th-Oct-19 to 14th-Mar-20 Estimated Occupancy: 90%	228	228	123	123	115	123	228	254	230	27	-	123	123	1223	8.74L/s
Site 3: Manhattan, Canberra, ACT Monitoring Dates: 14th-Dec-19 to 14th-Mar-20 Estimated Occupancy: 95% (15% of apartments are 'short term')	522	524	330	330	330	330	527	536	525	4	-	331	[b]330	2912	18.2L/s
Site 4: Braddon, Canberra, ACT Monitoring Dates: 17th-Jan-20 to 14th-Mar-20 Estimated Occupancy: Unknown	189	158	124	-	117	115	150	178	171	2	2	117	[c]115	859	8.33L/s

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.*

https://www.waterdemand.com.au/

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

HCAA Water Demand Investigation

Analysis

Water consumption data was analysed for:

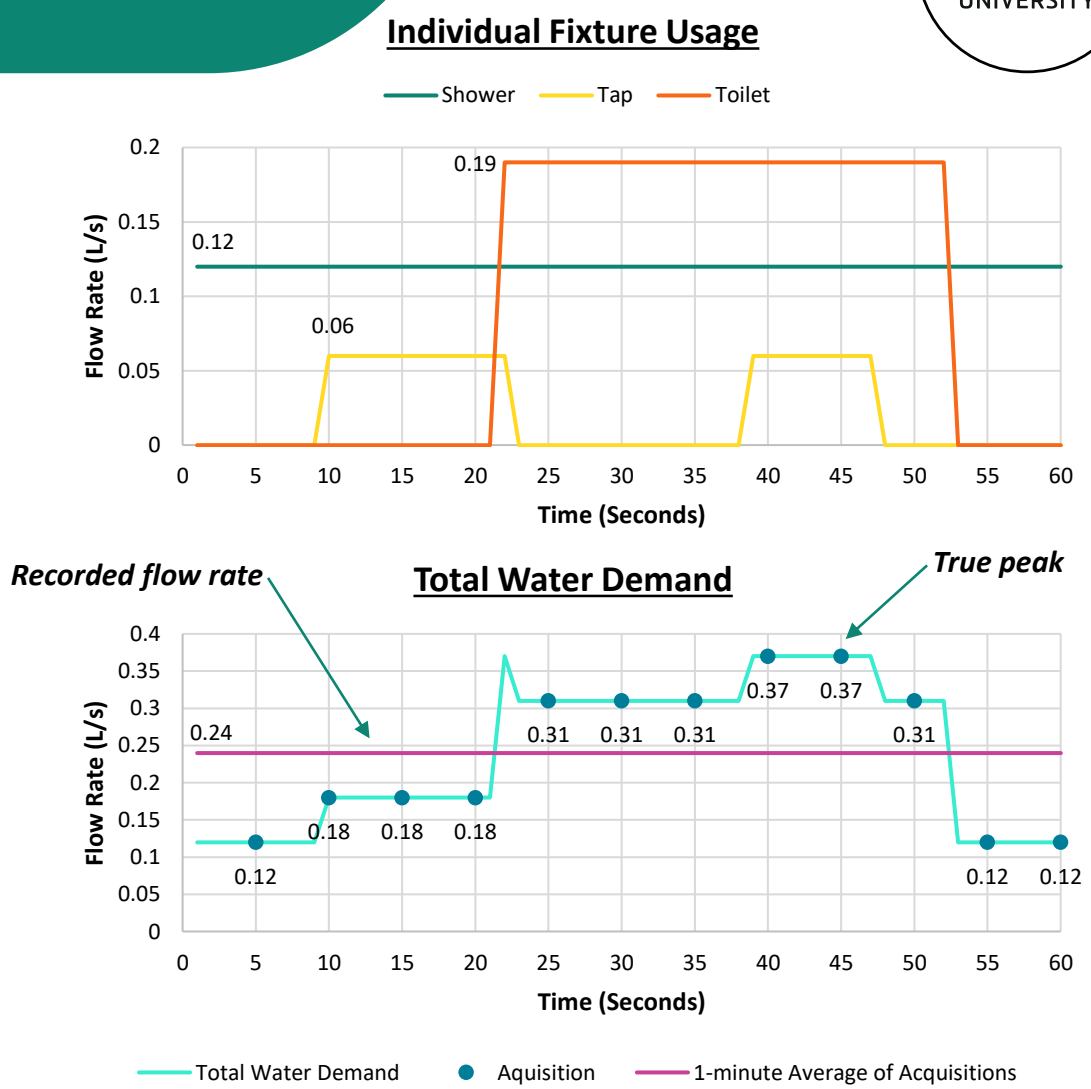
- Peak flow rate.
- Flow rate frequencies.
- Comparison against Australian and comparable international plumbing codes:
  - Australian/New Zealand cold-water service standard: AS/NZS3500.1:2018.
  - German cold-water service standard: DIN 1988-300 2012.
  - IAPMO's Water Demand Calculator (https://www.iapmo.org/water-demand-calculator/).
  - Verification Method (under investigation by the ABCB)

HCAA Water Demand Investigation

Limitations

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).



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

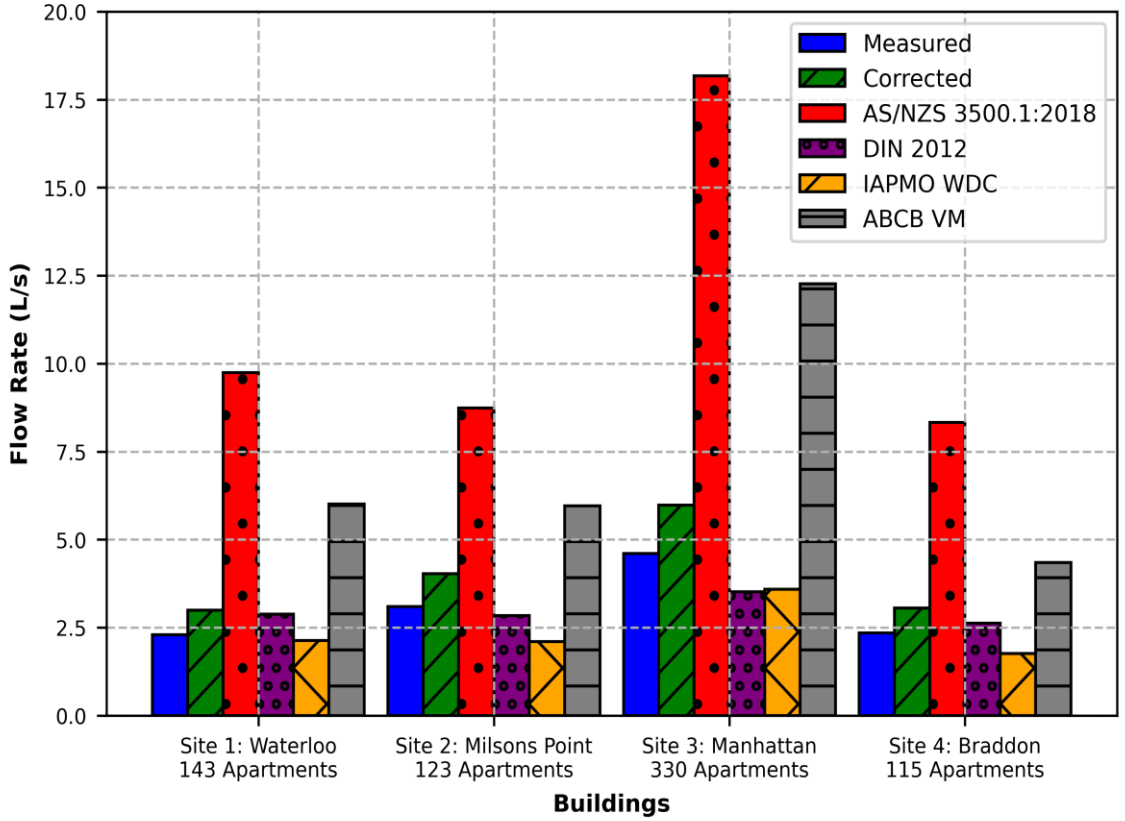
Site [Monitoring Days]	Apartments	Fixtures	Measured	[a] Corrected	[b] 99th Percentile Flow	AS/NZS 3500.1:2018	DIN 1988-300:2012	IAPMO WDC	ABCB VM	[c] % AS/NZS 3500.1 Overestimation
1 Waterloo, NSW [215]	143	1291	2.3	**2.76**	1.65	**9.74**	2.88	2.13	6.01	**326%**
2 Milsons Point, NSW [149]	123	1223	3.1	**3.75**	1.85	**8.74**	2.84	2.10	5.96	**217%**
3 Manhattan, ACT [92]	330	2912	4.6	**5.52**	3.75	**18.2**	3.52	3.59	12.3	**304%**
4 Braddon, ACT [58]	115	859	2.35	**2.82**	1.50	**8.33**	2.62	1.76	4.35	**273%**

Notes:

[a] Corrected value assume 1.3 of measured values.

[b] Assumes 99th percentile flow within peak hour of water consumption for all monitoring days.

[c] Percentage calculated using corrected values.



Measured and corrected (multiplied by a factor of 1.3) peak flow compared against Australian and International plumbing codes that predicted 99th percentile design flow rates

"Assuming corrected peak flow rate values: AS/NZS 3500.1:2018 overestimates peak flow rates between 217%-326%."

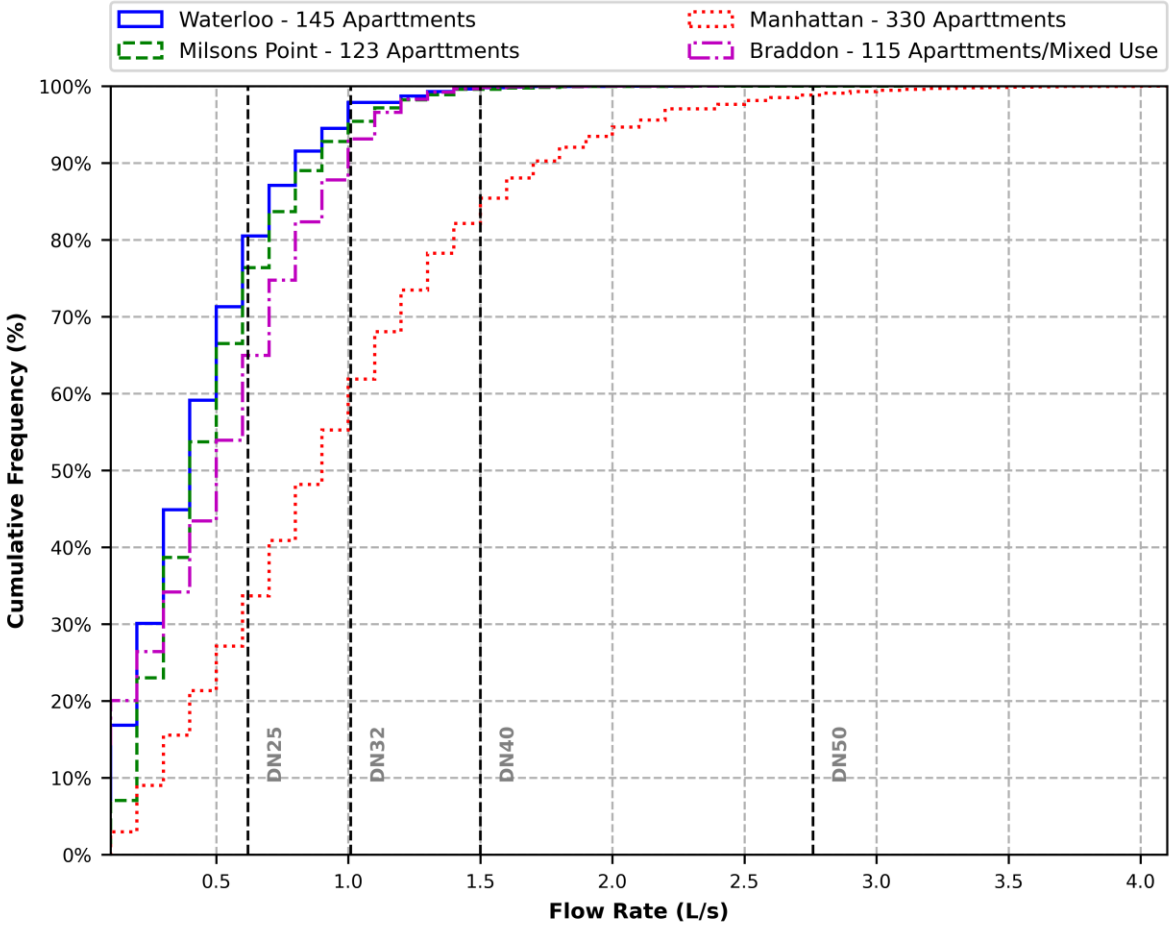
HCAA Water Demand Investigation

Results: Flow Rate Frequencies

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.



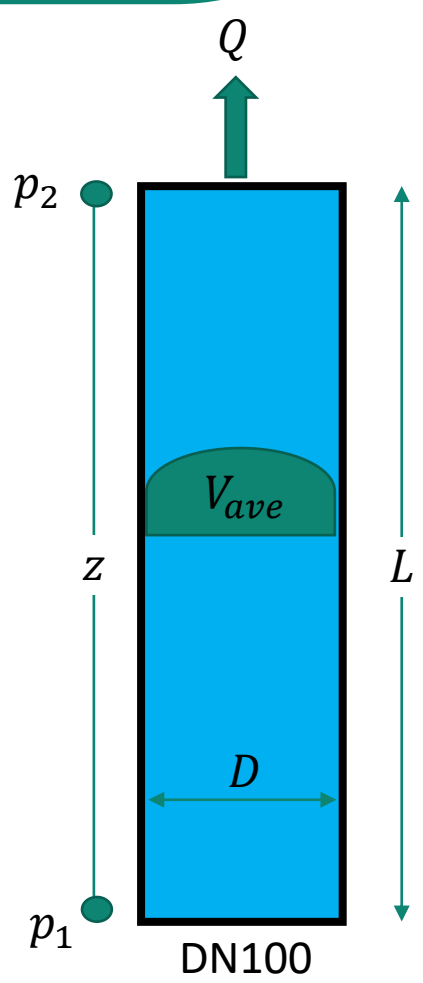
Cumulative distribution of flow rates observed in monitored buildings, shown against alternative pipes sizes assuming 1.5m/s flow velocity (e.g. 1.5L/s flow will result in ~1.5m/s velocity in DN40 copper pipes)

Hydraulic Modelling
Aim

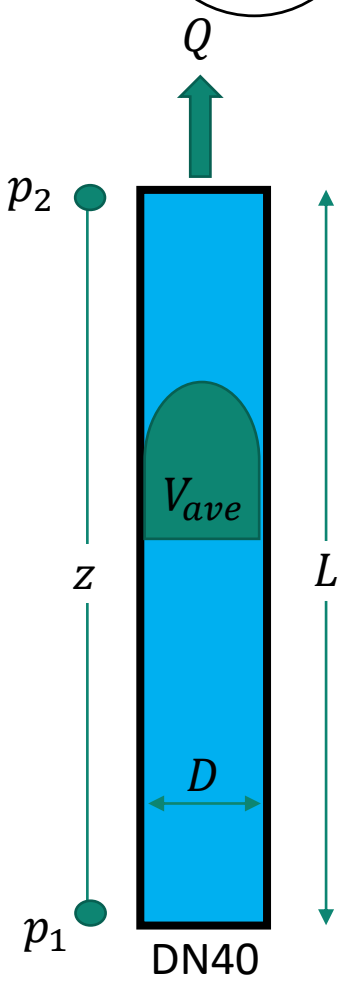
Hydraulic modelling was performed to:

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)



Current State



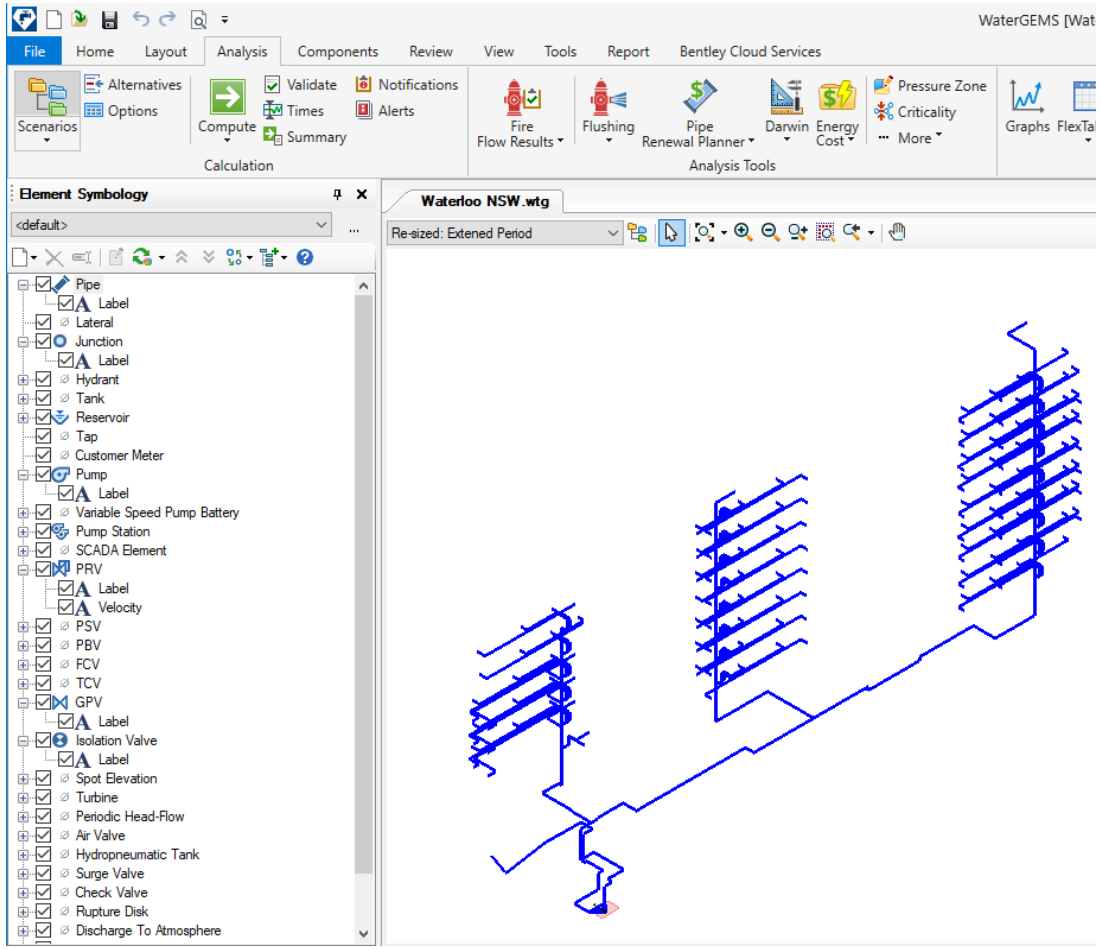
Future State

Hydraulic Modelling
Method

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:

	As Built System	Resized System
Design Demand (9.75L/s)	(1) Single Period	-
Monitored Demand (~2.90L/s)	(2) Single Period (3) Extended Period	(4) Extended Period



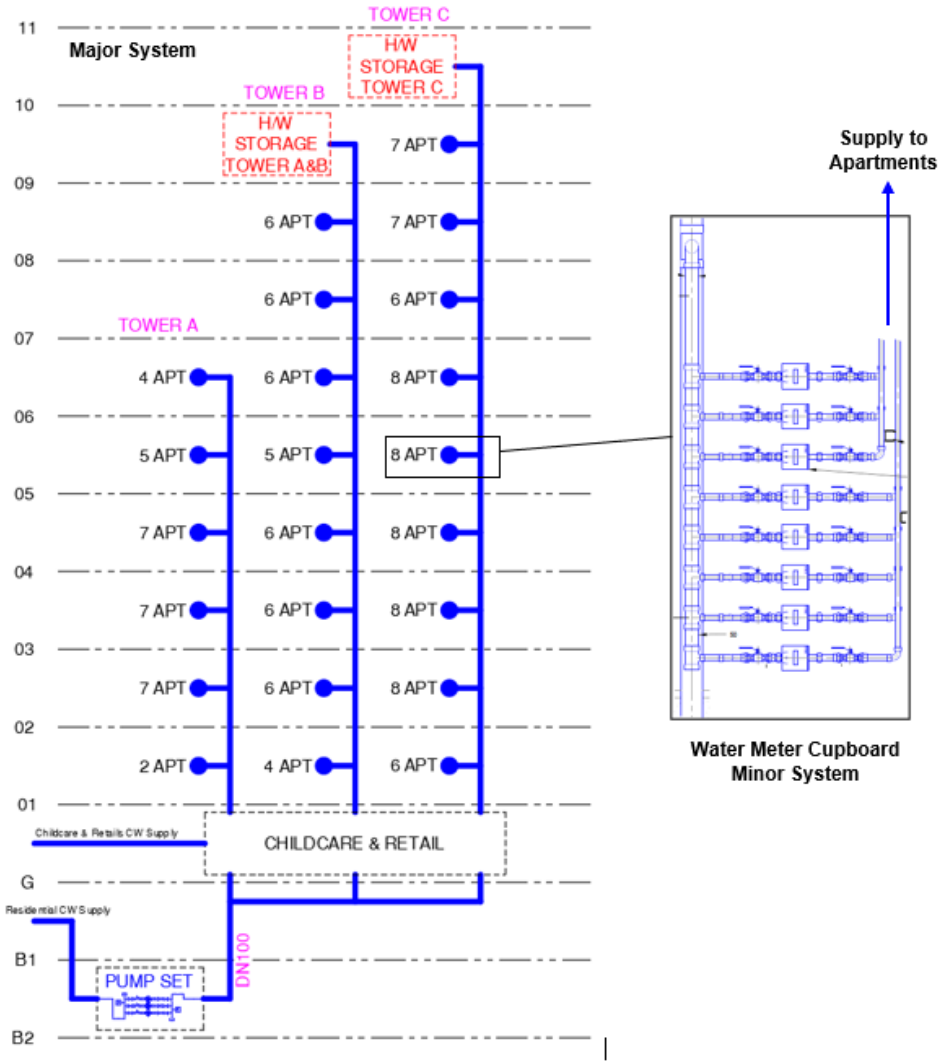
Screenshot of modelled cold-water service network in WaterGEMS hydraulic modelling software

Hydraulic Modelling

Building Layout

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.



Simplified cold-water service network: Waterloo, NSW (Site 1)

Hydraulic Modelling

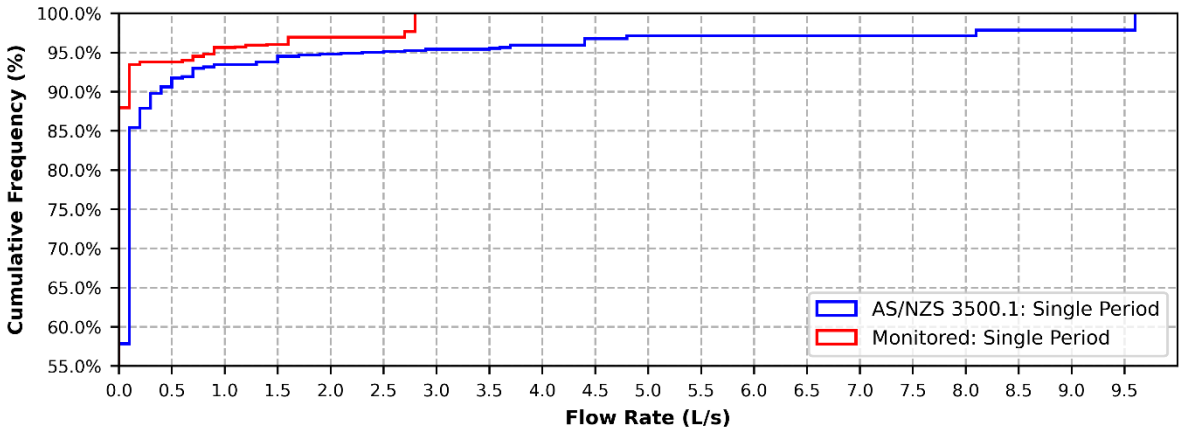
Results: Flow Rates

Single period scenarios considered flow rate in all pipes.

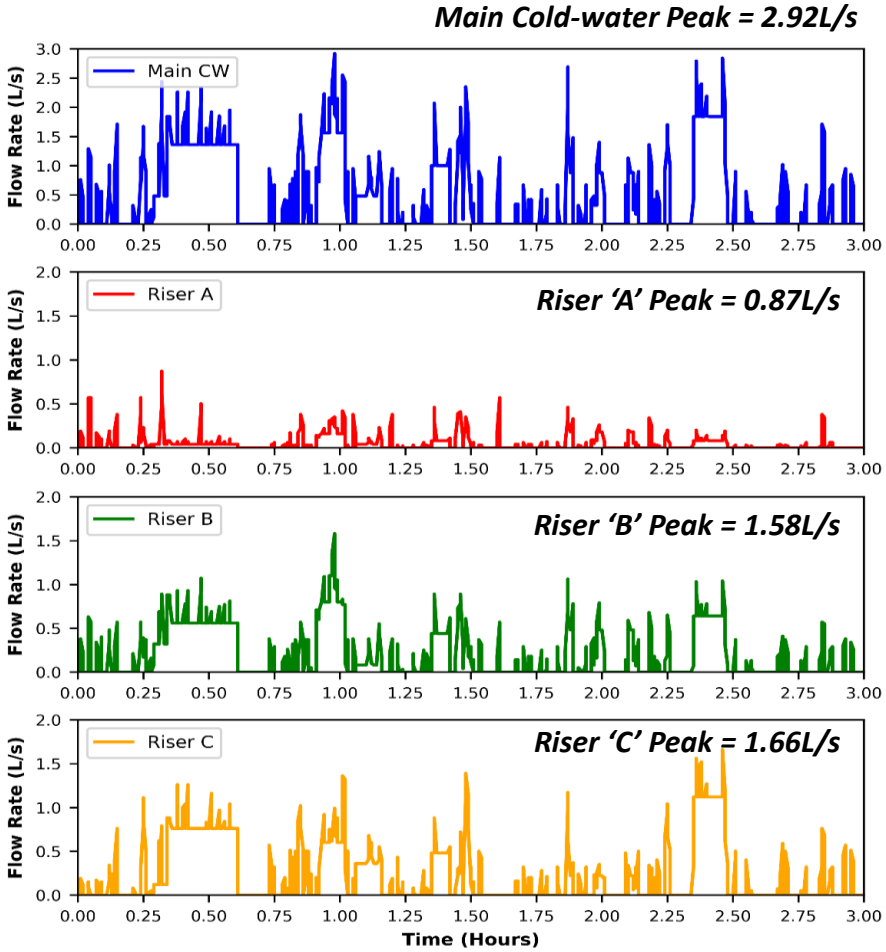
- Large gap between design (AS/NZS 3500.1) and measured flow rates.

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.



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

Hydraulic Modelling

Results: Pipe flow Velocity

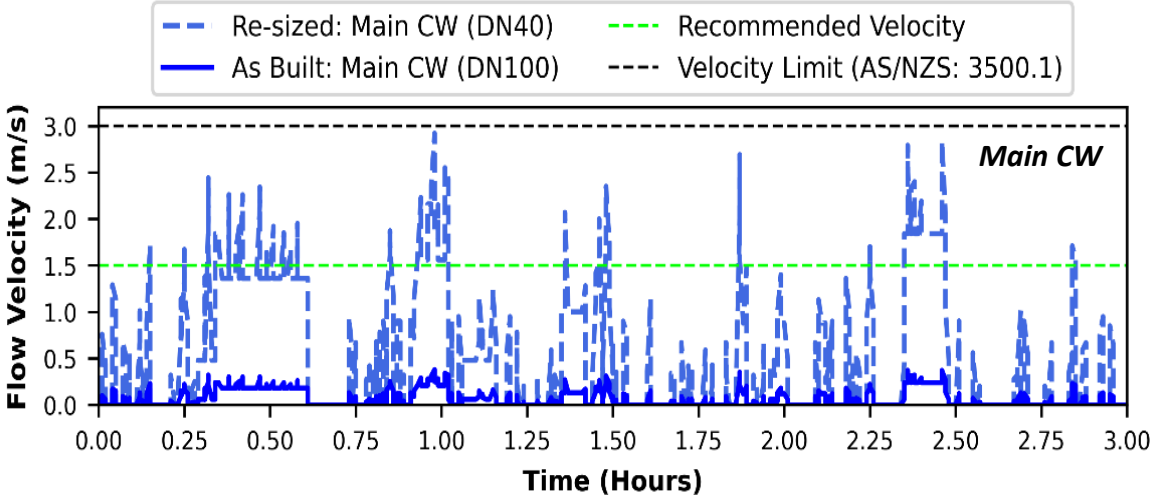
Single period scenarios:

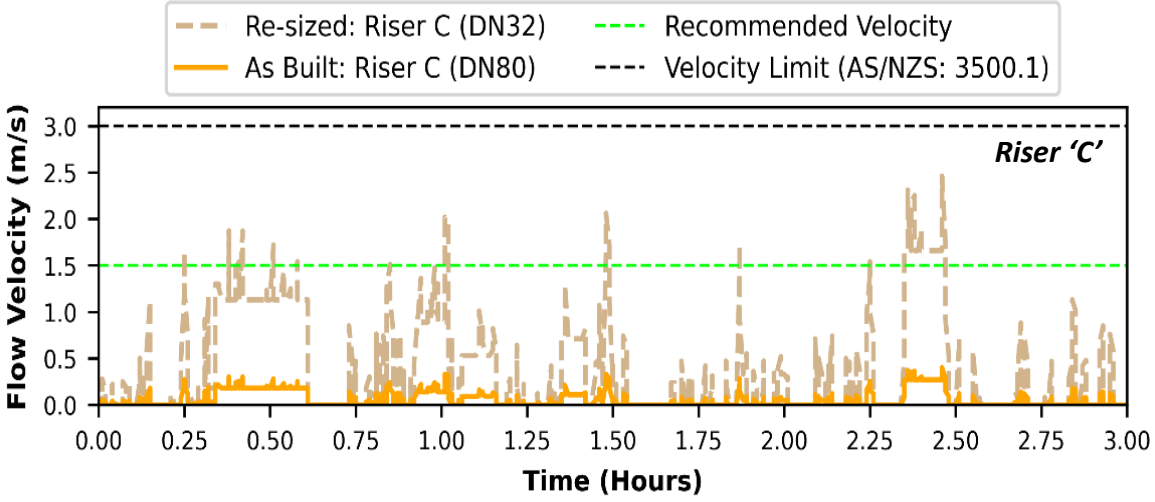
- AS/NZS 3500.1 peak velocity = 1.2m/s.
- Monitored = 0.5m/s.

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

Extended period scenarios:

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

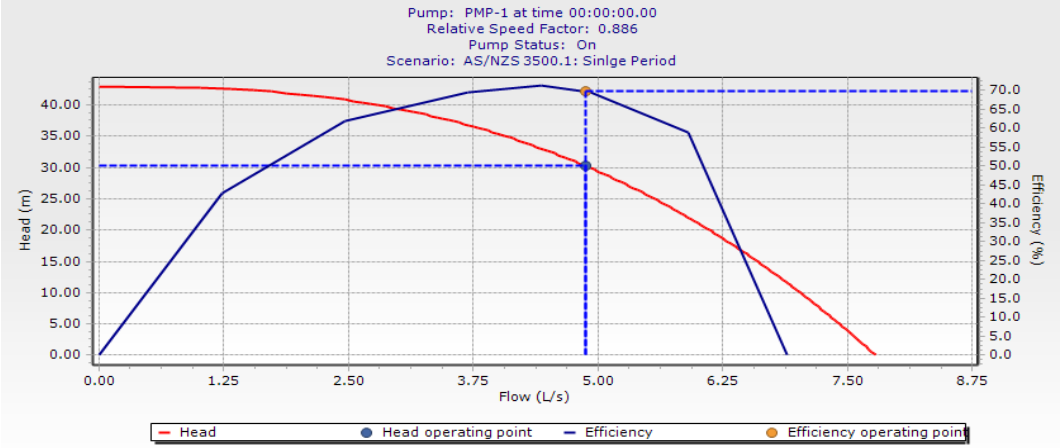
Hydraulic Modelling

Results: Hydraulic Profile & Pump Performance – Single Period

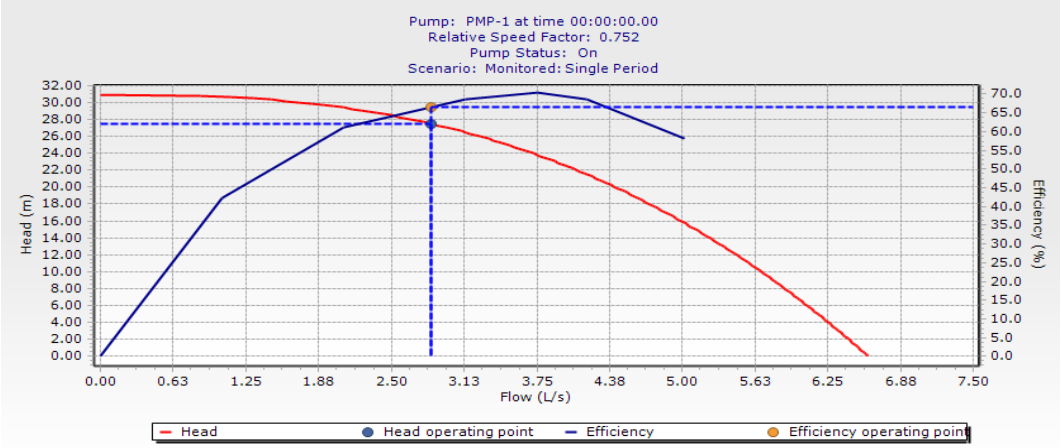
Pump parameters were set to achieve 250kPa at most hydraulicly disadvantaged apartment node (level 10, tower 'C').

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%



Pump performance curve: AS/NZS 3500.1 single period scenario



Pump performance curve: Monitored single period scenario

Hydraulic Modelling

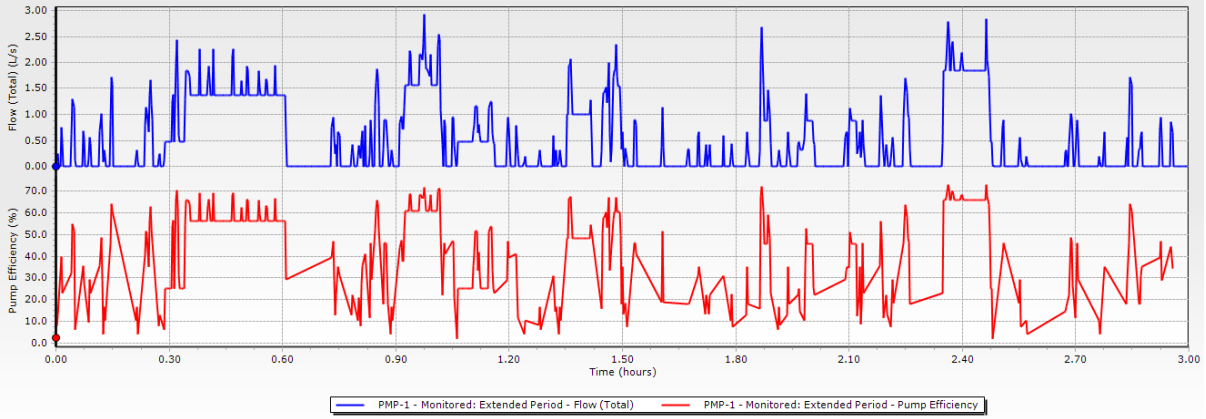
Results: Hydraulic Profile & Pump Performance – Extended Period

As built system = minimal variation

Monitored (extended period) results

- Pressure = 25.63 – 27.48m head
- Average Operating Efficiency = 20.0%

'As Built Pump'
Triplex VSD
350kPa @ 5L/s
75% BEP



Pump flow and efficiency: Monitored extended period scenario

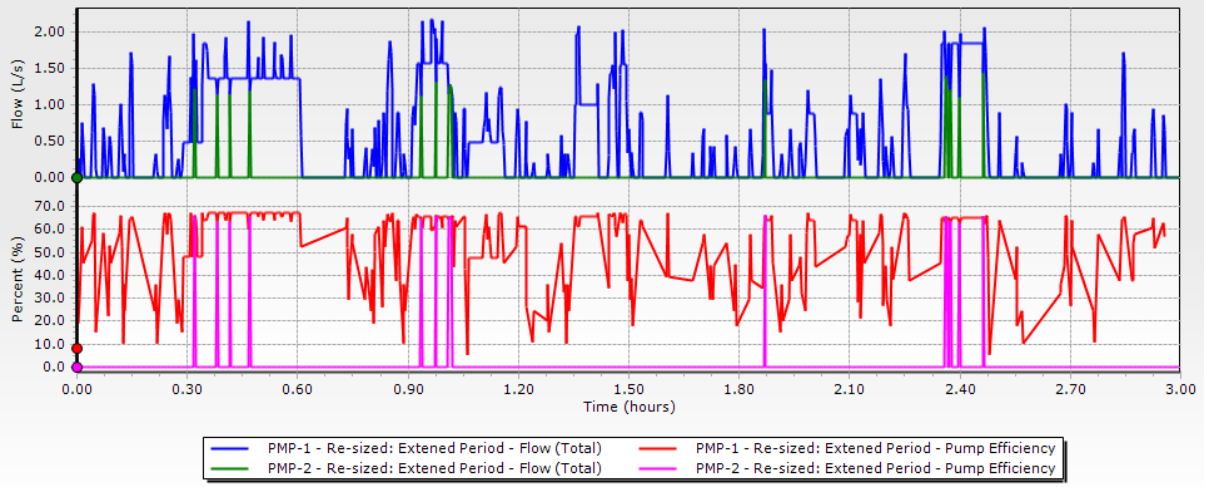
Re-sized system = significant variation

(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)

'Re-sized Pump'
Triplex VSD
600kPa @ 1.7L/s
67.2% BEP



Pump flow and efficiency: Re-sized extended period scenario

"Average flow rate of 3-hour period was 0.48L/s."

Hydraulic Modelling

Results: Plumbing hardware – Extended Period

Plumbing devices are design to operate with a specified flow velocity range.

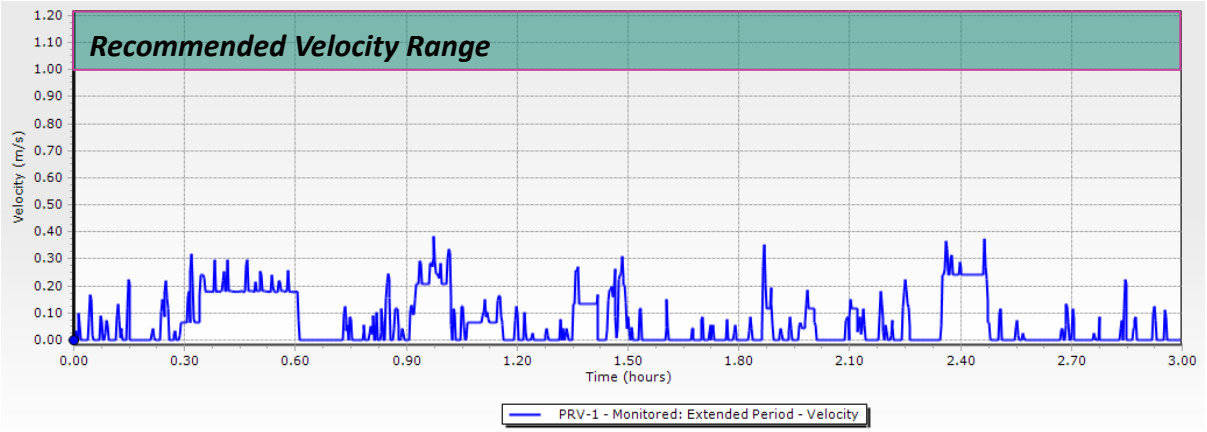
PRV recommended flow velocity range = 1.0-2.0m/s.

As Built system

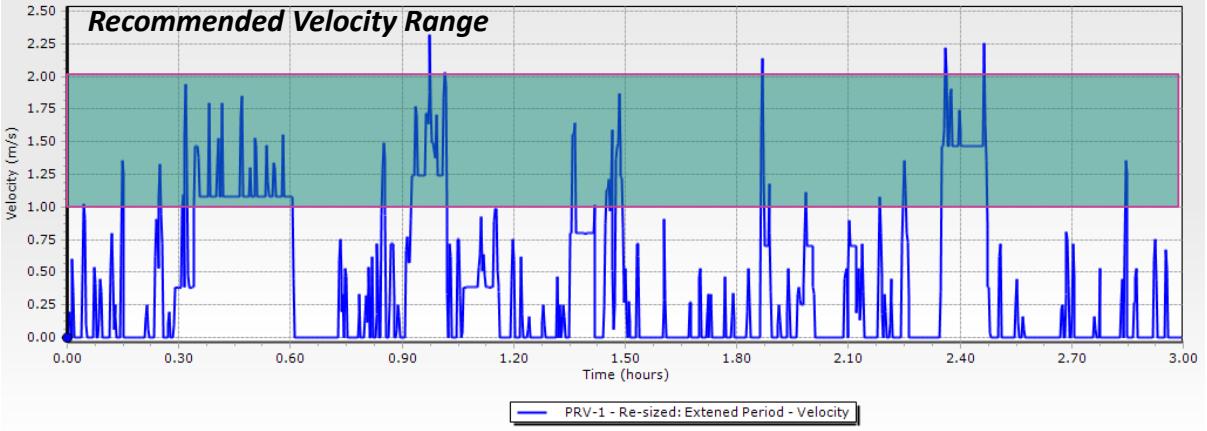
- Velocity range = 0-0.4m/s

Re-sized system

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



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

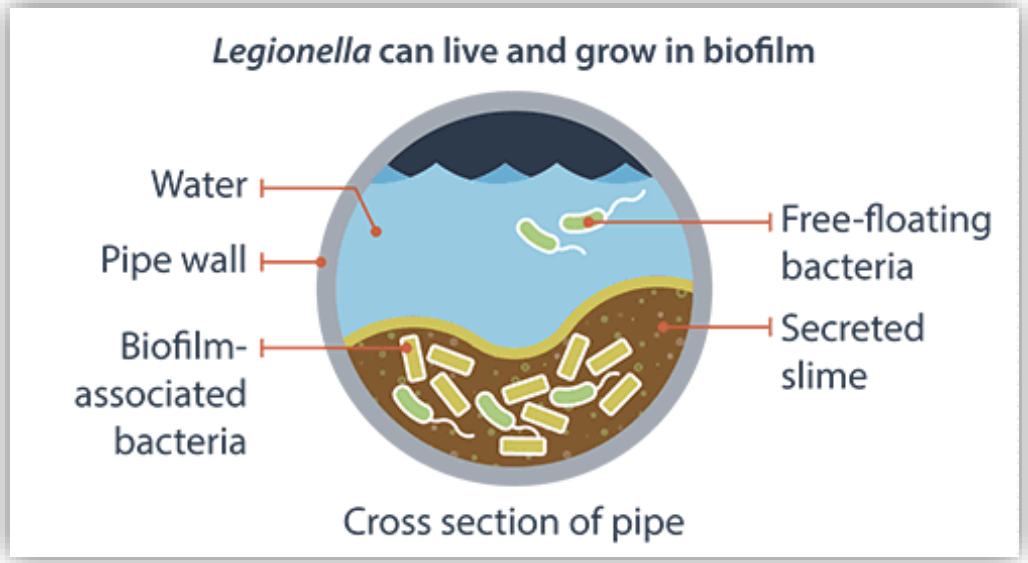


Mains cold-water PRV (DN40) flow velocity observed: Re-sized extended period scenario

Implications
Overestimation of Peak Flow

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.

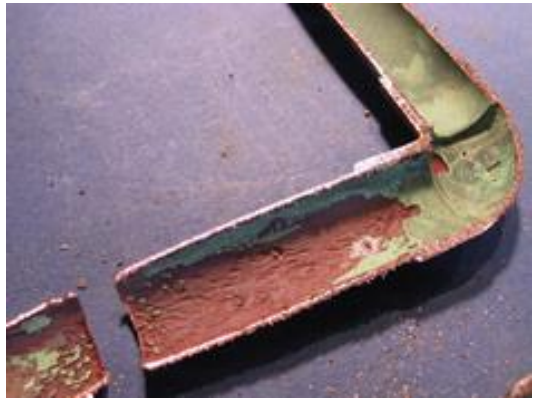


Source:https://www.cdc.gov/legionella/wmp/overview/growth-and-spread.html

Implications
Reduced Pipe Size

Simply reducing the pipe size may bring other problems!

- Higher velocity
  - Erosion-corrosion



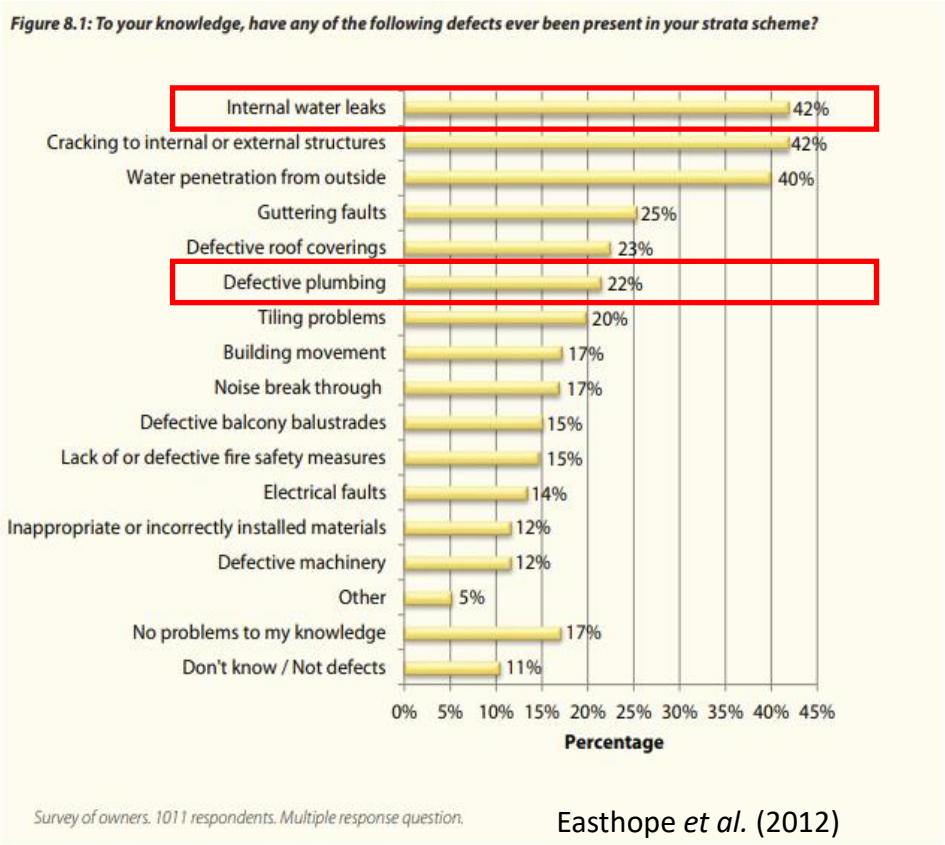
https://www.duffnerengineering.com/erosion-corrosion-of-copper-tube/

- Wider range of flow conditions
  - High energy consumption and CO2 emission

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)

- Water hammer
  - Noise and premature failure



Easthope *et al.* (2012)

Recommendations

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

Discussion - Interactive

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 it's Student Scholarships Program in the coming weeks.

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

Dr James Gong - email: james.gong@deakin.edu.au

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