

ABCB PIPE SIZING VERIFICATION METHOD – WORKED EXAMPLES

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EXECUTIVE SUMMARY

The Australian Building Codes Board (ABCB) has developed a new verification method (VM) for estimating probable simultaneous flow rates (PSFR) in water reticulation systems. The VM presents an alternative to the deemed-to-satisfy (DTS) method provided in the AS/NZS 3500 series. The VM allows designers to modify calculation inputs depending on the expected usage profiles of downstream plumbing fixtures.

Lucid Consulting Australia was engaged by the ABCB to test the VM by sizing the domestic cold water (DCW) and domestic hot water (DHW) systems of three previous projects and comparing the results to equivalent DTS sized systems. The three worked examples (WE) selected were: a high-rise multi-residential development (WE1), a high-rise office development (WE2) and a hospital development (WE3). Pipework plan layouts were developed for each WE. Each system was sized using the DTS method and then sized using the new VM method. The results were then compared.

PSFR's were reduced by the VM by around 20-50% for most pipe sections. The reduction was generally greater in pipes that serviced a larger number of fixtures. The VM only estimated PSFR's higher than the DTS approach where pipes serviced a low number of fixtures or a significant number of showers were downstream of that section of pipe.

Showers were found to have a significantly larger effect on the PSFR's estimated by the VM compared than the PSFR's estimated by the DTS method. An example of this was the DCW pipes servicing the WE2 end-of-trip facilities, which included 14 showers. Pipe sections servicing this area were increased by up to 250% by the VM. Further to this, DCW and DHW pipes servicing only 1 shower were sized as 15mm by the DTS approach and 20mm by the VM.

A bill of quantities and cost estimates were produced for each system to assess the cost differences between the VM and DTS systems. The VM resulted in an overall cost reduction for each WE, but certain sections of each systems were increased due to the effect of showers.

	DTS	VM	% Reduction Due to VM
WE1 DCW System	\$479,508.80	\$379,948.10	21%
WE1 DHW System	\$434,688.80	\$421,570.90	3%
WE1 Total	\$914,197.60	\$801,519.00	12%
WE2 DCW System	\$241,304.80	\$209,683.80	13%
WE2 DHW System	\$71,798.20	\$72,114.40	0%
WE2 Total	\$313,103.00	\$281,798.20	10%
WE3 DCW System	\$810,377.50	\$703,215.90	13%
WE3 DHW System	\$448,459.60	\$417,193.80	7%
WE3 Total	\$1,258,837.10	\$1,120,409.70	11%

During the WE1 and WE2 pipe sizing exercise, DHW VM inputs for tempered fixtures did not consider the reduction in DHW demand caused by thermostatic mixing valves. This was altered for WE3 but may have led to overly conservative VM sizing results in WE1 and WE2.

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ABBREVIATIONS

Acronym	Description
ABCB	Australian Building Codes Board
BOQ	Bill of Quantities
DCW	Domestic Cold Water
DHW	Domestic Hot Water
DTS	Deemed to Satisfy
LU	Loading Unit
PSFR	Probable Simultaneous Flow Rate
RPZD	Reduced Pressure Zone Device
TMV	Thermostatic Mixing Valves
VM	Verification Method
WC	Water Closet
WE	Worked Example
WELS	Water Efficiency Labelling and Standards Scheme

An explanation of terms used in this report can be found in Appendix A.

1. INTRODUCTION

1.1. OVERVIEW

One challenge of designing water reticulation systems within buildings is accurately estimating probable simultaneous flow rates (PSFR). The approach presented in the deemed-to-satisfy (DTS) AS/NZS 3500.1:2018 and AS/NZS 3500.4:2018 (referred to as AS3500 this report) for estimating PSFR's is based on the work of Roy B Hunter in the early 20th century (Hunter 1940). This method assigns a loading unit (LU) value to each common type of plumbing fixture and uses a probabilistic approach to estimate PSFR's. The drawback of this approach is that it does not consider different building types and different fixture usage profiles.

The Australian Building Codes Board (ABCB) has developed a verification method (VM) which presents an alternative to the DTS method for estimating PSFR's in water reticulation systems. This VM allows the designer to alter the inputs used in the calculation, as oppose the DTS approach where these are fixed.

The ABCB engaged Lucid Consulting Australia (Lucid) to test the new VM on three previous projects that Lucid has been involved in. For each of the three worked examples (WE), the domestic cold water (DCW) and domestic hot water (DHW) systems were sized using the VM and then compared to equivalent DTS sized systems.

1.2. SCOPE AND LIMITATIONS

The intent of the investigation was to test the VM on DCW and DHW systems as if it were available in the current National Construction Code (NCC). As such, the level of effort made to reach accurate results using the VM and DTS approaches matched Lucid's expectation of the amount of effort a normal designer would make.

Due to time and budget constraints, the VM was only tested on three previous projects.

Floor plans for most tenancies within each WE were not available during the investigation. In the DCW systems, this was overcome by assuming a PSFR for each tenancy's capped water supply. DCW pipework within the tenancy was not included in this investigation. In the DHW systems, a fixture make-up and pipework quantities were assumed and included in the investigation.

Only elements of the plumbing system that is sized primarily using PSFR were included in this investigation. As such, elements such as plumbing fixtures and storage hot water systems were not included.

Cost estimates were based on Lucid's in-house data from previous project experience throughout Australia. External cost verification or tendering to verify accuracy of cost estimates was outside the scope of this investigation.

Specific details on each project have not been included in this report to protect confidentiality.

2. METHODOLOGY

The methodology that was used in this investigation can be summarised as follows;

A) PROJECT SELECTION

Identify suitable previous projects. The previous projects should:

- Be of different building types and contain different DCW and DHW reticulation strategies, to test the VM in diverse settings,
- Have complete architectural and plumbing fixture layouts available,
- Have previously designed pipework plan layouts available,
- Be of a common building type and a typical building of that type,
- Be greenfield developments or have complete DCW and DHW systems designed as 1 package of works.

B) CREATE PIPEWORK PLAN LAYOUTS

Create DCW and DHW plan layouts for each WE. The plan layouts should:

- Capture all pipework reticulation from the authority connection to each individual plumbing fixture,
- Capture all pipework and fittings required to construct each system, including offsets around major obstacles such as structure and mechanical ductwork,
- Show all equipment in each system that would have a measurable impact on the cost estimates, including; isolation valves, meters, pressure reducing valves, balancing valves, thermostatic mixing valves (TMV), tanks, pumps and backflow valves.

C) PSFR CALCULATION

Calculate the PSFR for every part of the DCW and DHW system, using both the DTS and VM approaches.

The PSFR's should make allowances for all demands on each system including DHW plant, irrigation and mechanical make-up water.

The DTS and VM approaches should be applied as if available to designers within the current NCC.

D) PIPE AND EQUIPMENT SIZING

Using the PSFR's calculated, select suitable pipework sizes and equipment selections through-out each system.

E) COST ESTIMATES

Estimate the cost to construct each system.

F) PSFR AND COST COMPARISONS

Compare the PSFR's and costs between each system.

3. BASIS OF ASSESSMENT

3.1. PROJECT SELECTION

The following building types were selected as being suitable for this investigation:

- High-rise multi-residential,
- High-rise commercial office,
- Hospital.

To select a suitable project for each building type, Lucid used previous projects where hydraulic consultancy services had been offered. This provided access to architectural layouts and previous DCW and DHW plan layout drawings.

Each development is located within a major Australian city and has an authority water connection in the adjacent street.

Specific details on each project have been removed to protect confidentiality.

WORKED EXAMPLE 1: HIGH-RISE MULTI-RESIDENTIAL

The project selected for WE1 is described in Table 3.1.

Description	<ul style="list-style-type: none"> ▪ Greenfield, 20 storey, multi-residential building. ▪ Mixture of single bedroom and two-bedroom apartments. ▪ Small café style tenancy on ground floor. ▪ Small shared gym, sauna, kitchen, function space and bathrooms on top floor. ▪ Approximately 98% of all plumbing fixtures are located within apartments.
Availability of Plans	<ul style="list-style-type: none"> ▪ Full architectural and plumbing fixture layouts available. Tenancy layout not available. ▪ Coordinated DCW and DHW plan layouts available for entire building apart from café style tenancy.
Total Internal Floor Area	~19,600 m ²
Plant Locations	<ul style="list-style-type: none"> ▪ DCW break tank and DCW Pumpset located in a plantroom on the Ground Floor. ▪ Central DHW plant located in a plantroom on Level 20.
DHW Strategy	<ul style="list-style-type: none"> ▪ Parallel DHW loops running vertically down plumbing ducts on typical floors ▪ DHW return pipework combines at high level on level 6. Single return back to Level 20 DHW plant ▪ Re-circulation pumpset in level 20 Plantroom ▪ Single UAT basin on ground floor fed by instantaneous HWU

Table 3.1: WE1 Description

WORKED EXAMPLE 2: HIGH-RISE COMMERCIAL OFFICE

The project selected for WE2 is described in Table 3.2.

Description	<ul style="list-style-type: none"> ▪ Greenfield, 18 storey, mixed-use development. ▪ The building consists of a commercial side and multi-residential side. Each side is almost completely separated architecturally and is serviced by separate non-interconnecting plumbing systems. ▪ Basement includes end-of-trip facilities and carparking. ▪ Four small café-type tenancies located on ground floor of the commercial side. Each tenancy was provided with a capped DCW supply. ▪ Commercial side includes 16 floors consisting of one large commercial tenancy space per floor. Each commercial tenancy was provided with a capped cold-water supply to each floor.
Availability of Plans	<ul style="list-style-type: none"> ▪ Full architectural and plumbing fixture layouts available. ▪ Coordinated DCW and DHW plan layouts available. ▪ Previous design had all water closets (WC) serviced by non-potable water system.
Total Internal Floor Area	~22,000 m ²
Plant Locations	<ul style="list-style-type: none"> ▪ DCW break tank and DCW Pumpset located in plantroom on Ground Level. ▪ Central DHW plant located on roof plantdeck. ▪ Mechanical services cooling tower on roof plantdeck.
DHW Strategy	<ul style="list-style-type: none"> ▪ Central DHW Plant on Level 17 ▪ Single DHW flow and return loop running vertically ▪ Re-circulation pumpset in level 17 plant ▪ Tenancies are not connected to main DHW loop. DHW supply for all tenancies serviced by small hot water units.

Table 3.2: WE2 Description

The purpose of this WE was to test the VM on a high-rise commercial type building. To achieve this, the residential side of the building was ignored. This alteration has no impact on the DCW and DHW systems servicing the commercial side of the building.

WORKED EXAMPLE 3: HOSPITAL

The project selected for WE3 is described in Table 3.3.

Description	<ul style="list-style-type: none"> ▪ 3 storey, 200+ bed, Class 9A hospital. ▪ The facility has been built and re-developed at various times across its history. ▪ Facility includes emergency department, maternity ward, surgery theatres, small café, medical imaging services and care rooms. ▪ Development contains one small café-type tenancy and one small pharmacy type tenancy.
Availability of Plans	<ul style="list-style-type: none"> ▪ Architectural and plumbing fixture layouts available for approximately 70% of the facility. ▪ Available DCW and DHW plan layouts are approximately 40% complete.
Total Internal Floor Area	~17,500 m ²
Plant Locations	<ul style="list-style-type: none"> ▪ Central DHW plant located on roof plantdeck. ▪ DCW break tank, DCW filtration & DCW pumpset in basement plantroom. ▪ Mechanical services cooling tower on roof plantdeck.

Table 3.3: WE3 Description

For the purpose of this investigation, the hospital was treated as a greenfield development being built in one stage. This allows the DCW and DHW plan layouts to be designed as one complete system.

3.2. PLAN LAYOUTS

DCW and DHW plan layouts were required for each WE to allow measurement of pipework and fitting quantities. Existing plan layouts were used where available. If the existing plan layouts were incomplete, they were used as a guide and a new design was developed.

Using existing layouts allows for a more accurate representation of the constructed arrangement, as pipe layouts have been coordinated with the structure, voids, client requirements, and other services during the previous design process.

Plan layouts were developed approximately to the level of detail sufficient to capture most offsets and bends required to complete the installation. It is likely that these design layouts will slightly under-estimate all pipework and bends required to reticulate around obstacles encountered during construction.

WE1

The available DCW and DHW plan layouts for WE1 were already complete and suitable for this investigation. These plans were adopted and were not modified.

WE1 included a small café style tenancy on the ground floor. Layouts and floor plans for this tenancy were not available.

WE2

DCW and DHW pipework layouts were available from the previous project and were utilised in this investigation.

The WE2 development included four small tenancies on ground floor, and 1 large office space on each typical floor. A capped DCW supply is provided to each tenancy. The tenant will then generally supply all pipework, fixtures and hot water units downstream. Most floor plans for these tenancies were not available, which is typical for the base-build stage of a project. To overcome this, a loading is generally assumed for each future tenancy based on the size and expected use of that tenancy. A conservative allowance is usually adopted to prevent capacity issues in the base build systems, should the future tenants require above average water requirements.

Lucid has access to some of the final tenancy layouts for the development used in WE2. From these layouts, an approximate average fixture make-up of 2 kitchen sinks, 1 dishwasher and 1 boiling water unit was reached. The office tenancy layout assumed for this WE, which has been increased to provide redundancy, consisted of 3 kitchen sinks, 2 dishwashers and 2 boiling water units. The assumed fixtures were located through-out the tenancy in a similar layout to the available tenancy layouts.

All WC's within the WE2 development were serviced by a non-drinkable cold water system. To simplify the investigation, this system was removed and the DCW plan layouts were modified and extended to service all WC's.

WE3

The project selected for WE3 was built and re-developed in multiple stages across the lifetime of the facility. Each time the building was re-developed or expanded, the plumbing systems were modified to suit the new arrangement. This resulted in the DCW and DHW pipework arrangements of the existing development being patchy and in-efficient compared to a layout which would be provided if the facility had all been built in one stage. The intent of this WE was to test the project on a greenfield hospital and therefore existing layouts were deemed not representative of a greenfield DCW layout. To overcome this, new DCW and DHW layouts were designed. The design intent, main run locations and plant locations were retained from the original design.

WE3 DCW

DCW systems within class 9A facilities usually have additional requirements that must be complied with, on top of the DTS requirements of AS3500.1. These additional requirements aim to ensure that the water supply is guaranteed at all times and that a consistent water quality is provided.

To ensure the water supply is maintained from the street infrastructure, class 9A facilities often require street connections from at least two independent DCW street mains. Two connections were implemented for WE3. The locations of the connections were adopted from the existing development.

To provide water supply security during maintenance within the hospital, the DCW supply is usually designed in a ring main configuration. This allows for sections of the DCW system to be isolated, without affecting the remainder of the facility. Other benefits such as future-proofing and reduction in stagnation can also be realised by a ring main design. For this WE, a ring main was implemented into each floor of the hospital.

A sketch summarising the DCW configuration is shown in Figure 3.1.

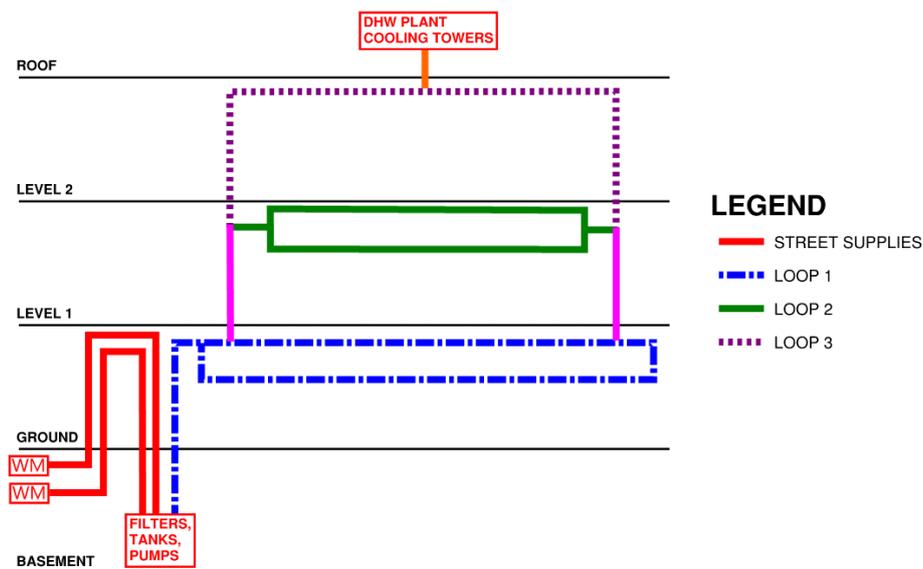


Figure 3.1: WE3 DCW Reticulation Strategy

WE3 DHW

As the available DHW pipework layouts were incomplete, a new DHW layout was designed. Multiple different DHW reticulation strategies could have been used in this investigation. A simpler design was chosen, as the design only needed to be sufficient to test the VM. A sketch summarising the DHW reticulation strategy is shown in Figure 3.2.

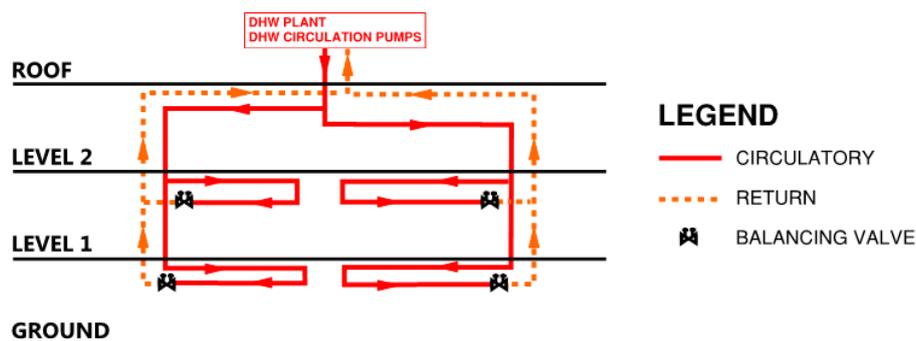


Figure 3.2: WE3 DHW Reticulation Strategy

3.3. PSFR CALCULATION

To facilitate a comparison between the DTS and VM approaches, each reticulation system was segmented into “pipe sections”. Each pipe section was assigned a designation to aid in sizing and preparation of cost estimates. An example label is shown in Figure 3.3, showing pipe section #54 of WE1.

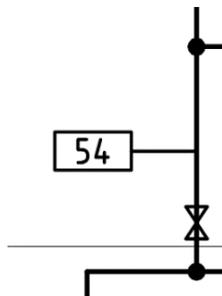


Figure 3.3: Pipe Section Example

To size each pipe section, the flowrate estimated for each pipe section must include all demands on that section of pipe, which includes:

- Demands due to plumbing fixtures downstream of that pipe section (referred to as “PSFR_{DTS}” and “PSFR_{VM}” in this report),
- For the DCW systems, the demand due to any DHW plant downstream of that pipe section (referred to as “PSFR_{DHWPlant}” in this report),
- For the DHW systems, the demand due to forced circulation (referred to as “Q_{Circ}” in this report),
- Any other full flow demands on that section of pipe that aren’t characterized by the above (referred to as “Q_{Other}” in this report).

The total PSFR that includes all demands is referred to as “PSFR_{Total}”. The equations below summarise how the PSFR_{Total} for each pipe section was calculated.

For the DTS method:

$$\text{PSFR}_{\text{Total-DTS}} = \text{PSFR}_{\text{DTS}} + Q_{\text{Other}} + \text{PSFR}_{\text{DHWPlant-DTS}} \text{ (DCW only)} + Q_{\text{Circ-DTS}} \text{ (DHW Only)}$$

For the VM method:

$$\text{PSFR}_{\text{Total-VM}} = \text{PSFR}_{\text{VM}} + Q_{\text{Other}} + \text{PSFR}_{\text{DHWPlant-VM}} \text{ (DCW only)} + Q_{\text{Circ-VM}} \text{ (DHW Only)}$$

PSFR_{DTS}

The method described in AS3500 involves summation of the loadings units (LU) associated with all fixtures downstream of that section of pipe, then converting the total LU's into a PSFR using the conversion tables provided.

AS3500.1 provides LU values for most fixtures found in typical plumbing systems. Where a LU value was not provided, a value was assumed based on similar fixture's where a LU value was provided and Lucid's understanding of that fixtures usage probability and required flowrate. There was a relatively small number of fixtures in the three projects selected that were not included in AS3500, so the impact on the final outcomes of this investigation due to the assumed values was assumed to be negligible. Table 3.4 provides a summary of the LU values used in this investigation that have been taken from AS3500.1.

Fixture	Loading Units
Water Closet	2
Bath	8
Basin	1
Shower	2
Sink (Standard Tap)	3
Laundry Trough	3
Washing Machine	3
Dishwasher	3
Hose Tap (15mm Size)	4

Table 3.4: LU Values From AS3500.1

Table 3.5 provides a summary of the LU values used in this investigation that have been assumed.

Fixture	Loading Units
Boiling Water Unit	1
Urinal	2
Flushing Rim Sink	2
Slop Hopper	2
Macerator	1

Table 3.5: Assumed LU Values

To convert LU's to a PSFR, AS3500 provides different conversion tables depending on the system type.

For DCW systems and deadleg DHW systems, AS3500 provides a conversation table for LU quantities from 1-60 but does not indicate how to estimate PSFR's above 60 LU. To overcome this, the extended LU tables provided in "Selection and Sizing of Copper Tubes for Water Piping Systems" by Barrie Smith (Smith 1976) was used for LU totals above 60.

For circulatory DHW systems, AS3500.4 provides a conversion table in Appendix O for LU quantities from 100-5000 but does not indicate how to estimate PSFR's below 100 LU. To convert LU quantities between 01-00, the deadleg conversion table was used.

The complete LU conversion table used in this investigation can be found in Appendix B.

PSFR_{VM}

The VM estimates PSFR's using a probability-based approach and the following inputs;

- The total number of fixtures or supply openings of a given type downstream of the pipework section,
- The average duration of flow in seconds for a given fixture type for one use,
- The average time in seconds between successive operations of any given fixture of a particular type, during the period of expected maximum usage frequency,
- The operating flowrate of a single fixture of a given type.

The full VM text can be found in Appendix C.

The ABCB provided a draft Excel calculator to assist in the application of the VM. An example output from the VM calculator can be found in Appendix E.

VM INPUTS

The accuracy of the results produced by the VM depends on the accuracy of the input values selected. The intent of this investigation was to test the VM as if it was available within the current NCC. The amount of effort made to reach accurate input values approximately matched Lucid's expectation of the level of effort an average designer would make.

VM inputs for operating flowrate were taken from the fixture selected in each project, where this was available. Where the actual fixture selections were not available, operating flowrates were assumed based on Lucid's past experience of typical fixtures for that type of development.

A complete fixture schedule was available for WE1, so the operating flowrates were taken from the actual fixture selections. Fixture selections were not available for WE2 and WE3, so these flowrates were assumed.

The input values selected for "the average duration of flow for a given fixture type for one use" and "the average time between successive operations during the period of expected maximum usage frequency" were based on anecdotal evidence from Lucid employees.

The VM inputs for WE1, WE2 and WE3 can be found in Appendix D.

PEAK PERIOD SIMPLIFICATION

The "period of expected maximum usage frequency" will be slightly different for each fixture within a plumbing system. Setting a different two-hour peak period for every fixture within each WE would be a time-intensive exercise and would not be reflective of how the Lucid expects the VM to be used by designers. To simplify the investigation, the peak two-hour period was assumed to be the same for all fixtures within the building, unless a significant group of fixtures had a distinctly different two-hour peak period from the remainder of the fixtures. This simplification should result in slightly more conservative PSFR estimates.

The following peak periods were identified for WE1:

- For the residential portion of the building and the Cafe, approximately 6-8am on a weekday. This would coincide with occupants getting ready to leave the apartments.
- For the level 20 common area, during weekend events or functions.

For WE2, the peak period was identified as being approximately 7.30-9.30am. This would coincide with office workers showering at work and all tenancies being occupied. No other significant groups of fixtures with a different peak usage period were identified.

The peak period for WE3 was deemed to be approximately 9.00-11.00am. This would coincide with facility being fully occupied, operating theatres being utilised, patients showering, and ward rounds being undertaken. No other significant groups of fixtures with a different peak usage period were identified.

VM INPUTS FOR TEMPERED FIXTURES

Thermostatic mixing valves (TMV) and tempering valves are used in DHW systems at hygiene fixtures to temper water down from the circulated temperature (usually 65-60°C) to a safer temperature (usually around 45°C) to reduce the risk of users being scalded. TMV's operate by automatically blending in cold water with the hot water to maintain the desired outlet temperature. There will generally be a deadleg pipe from the DHW circulatory main to the TMV, which will cool to the ambient temperature if not used for a period of time. When a fixture is first used after a period of downtime, the TMV will flushing through near 100% water through the hot supply until hot water reaches the valve. When water that is above the set temperature reaches the TMV, the valve will blend in cold water so that the outlet water temperature remains near the set temperature. Due to this, the flowrate drawn from the DHW system will initially be high and will then reduce as the TMV blends in cold water.

In WE1 and WE2, the higher first-stage flowrate was used for all tempered fixtures. The reduced second-stage flowrate was not factored into the VM DHW inputs in any way.

After WE2 was completed, it was recognized that this approach was leading to overly conservative results and was not taking advantage of the flexibility the VM approach offered. To address this, in WE3 all tempered fixtures were entered into the VM as two separate stages. The first 5 seconds of all tempered fixtures were assumed to draw 100% hot water. After 5 seconds, the flowrate drawn from the DHW system was assumed to drop to 60-70% of the full fixture flowrate.

For basins, it was assumed that for 50% of the time the fixture is used, users would not wait for more than 5 seconds for hot water to reach the tap. The "time between successive operations" input for the second-stage (lower) flowrate was therefore set to double the first stage.

For baths and showers, it was assumed that users will always use the shower through both stages. The input of "time between successive operations" for each stage was set the same.

A full list of VM inputs can be found in Appendix D.

WE3 DCW RING MAINS

The PSFR for each DCW ring main in WE3 was calculated based on every DCW demand being serviced by that ring main. Each loop was therefore classified as 1 pipe section and its size did not change.

As shown in Figure 3.1, Loop 1 services most of the ground floor fixtures as well as the Loop 2 and Loop 3. Therefore, Loop 1 effectively services the entire development and has the same PSFR_{Total} as the site authority connection.

PSFR_{DHWPLANT}

All three WE's included a central hot water plant servicing most the buildings hot water needs. A DCW supply must be provided to the DHW plant for make-up water, which must be allowed for the DCW sizing.

To estimate the PSFR of the DHW plant (referred to as PSFR_{DHWPlant} in this report), all fixtures serviced by the DHW plant were counted and either the DTS or VM approach was applied. The LU values and VM calculator inputs were unchanged from the DCW method (except to remove fixtures not serviced by the DHW plant, such as WC's).

It can be noted that the PSFR_{DHWPlant} is different to the PSFR_{Total} of the outlet of the DHW plant for all three WE, which is not accurate. The cause for this discrepancy was the order in which the investigation was undertaken. The PSFR_{DHWPlant} was calculated as part of the DCW part of the investigation using the deadleg PSFR conversation tables. The PSFR_{Total} of the outlet of the DHW plant was calculated in the DHW part of the investigation and utilised the Circulatory PSFR conversion table. This discrepancy will have led to slightly more conservative sizing of the DCW pipe sections servicing the DHW plant, but the effect on the overall outcomes of the investigation was assumed to be negligible.

The DCW PSFR and PSFR_{DHWPlant} peak events cannot occur simultaneously in the same pipe section, as it is not possible for a fixture to supply 100% cold water and 100% hot water flowrate simultaneously. To allow for both peak events in pipe sections servicing the DHW plant, the higher of the two PSFR's is used.

For DTS pipe sections which are upstream of the DHW plant:

If $PSFR_{DHWPlant-DTS} > PSFR_{DTS}$: $PSFR_{Total-DTS} = PSFR_{DHWPlant-DTS} + Q_{Other}$

If $PSFR_{DHWPlant-DTS} < PSFR_{DTS}$: $PSFR_{Total-DTS} = PSFR_{DTS} + Q_{Other}$

For VM pipe sections which are upstream of the DHW plant:

If $PSFR_{DHWPlant-VM} > PSFR_{VM}$: $PSFR_{Total-VM} = PSFR_{DHWPlant-VM} + Q_{Other}$

If $PSFR_{DHWPlant-VM} < PSFR_{DTS}$: $PSFR_{Total-VM} = PSFR_{VM} + Q_{Other}$

Refer to Figure 3.4 for an example of how this would be implemented for a DTS DCW main servicing a roof mounted DHW plant.

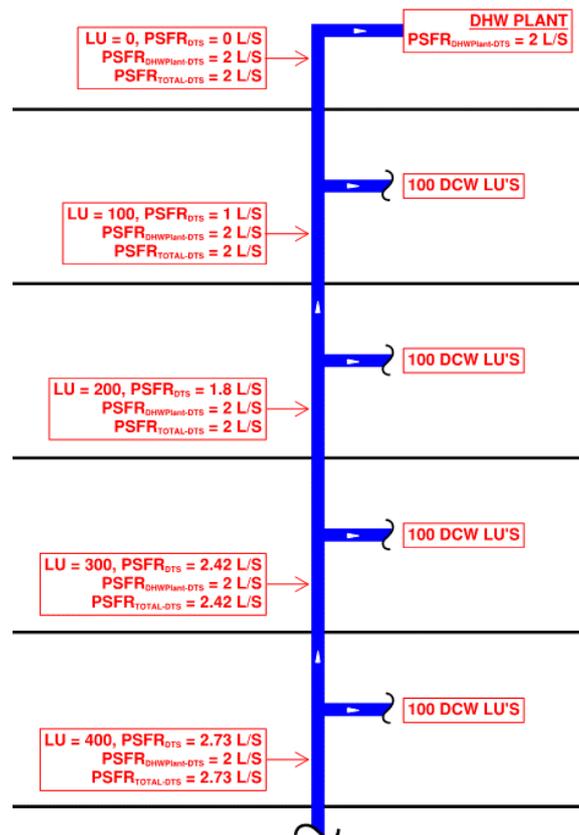


Figure 3.4: $PSFR_{DHWPLANT}$ Example

If the $PSFR_{DHWPlant}$ was not calculated using the same approach as the DCW demand for each system, the results of the investigation may be compromised by the $PSFR_{DHWPlant}$ being overestimated compared to the DCW demand. To illustrate this with an example; if the VM approach was applied to the example in Figure 3.4 and resulted in a 30% reduction in all DCW mains but the $PSFR_{DHWPlant}$ was still calculated using the DTS approach, the $PSFR_{Total-VM}$ would now be based on $PSFR_{DHWPlant-DTS}$ for at least two more floors down the building. This may result in an increase in pipe sizing and therefore cost. Further to this, Lucid expects the VM to be applied by designers to estimate the $PSFR_{DHWPlant}$ in most applications where the VM is applied to size the DCW system.

Q_{circ}

Larger DHW systems are typically designed as circulatory systems, where water is constantly circulated around the building and returned to the DHW plant for re-heating, to reduce hot water delivery times and microbial risk. A DHW circulatory system was present in all three WE.

Systems are typically designed with a 5°C temperature drop from the outlet of the DHW plant to the return back to the DHW plant. To size the circulatory system, the circulation flowrate required to maintain the 5°C temperature drop must be calculated (Q_{circ}). To estimate the required Q_{circ}, the following method was used:

1. The total length of each pipe size in the circulatory system was measured.
2. The total heat emission of the DHW system was calculated using the heat emission rates presented in Table 3.6.
3. The total heat emission and the following formula was used to calculate the required Q_{circ}.

$$Q_{circ} = \frac{W}{c_{water} \Delta T}$$

Where:

- W = Total Heat Emission of the system (W), calculated in Step 2.
- C_{water} = Specific Heat of Water = 4187 J/kg
- ΔT = Desired Temperature drop = 5°

Nominal Pipe Size (mm)	Heat Emission Rate for insulated Pipe (W/m)
15	8
20	11
25	13
32	16
40	17
50	20
65	24
80	26
100	35

Table 3.6: Pipework Heat Emission Rates

The heat emission rates in Table 3.6 were taken from “Selection and Sizing of Copper Tubes for Water Piping Systems” by Barrie Smith (Smith 1976).

Where parallel loops were present in the DHW designs, the total Q_{circ} was assumed to be equally split between each parallel loop.

SMALL TENANCY SIMPLIFICATION

Each of the three WE’s included small café-style tenancies. WE3 also included a small pharmacy tenancy. Fixture layouts were not available for these tenancies. In each development, these tenancies were provided with “cold-shell” provisions which consisted of a capped DCW supply.

For the DCW systems, a PSFR was assumed for each tenancy to overcome the lack of fixture layouts. The assumed PSFR’s were kept constant between DTS and VM systems.

For the DHW systems, the brief required the small tenancy hot water systems to be included in the investigation. Quantities of fixtures, pipework and fittings was assumed for each tenancy. The size of all pipework within each small tenancy was assumed to be the same size, the greatest PSFR_{Total} in the tenancy.

Given the small number and size of these tenancies, the effect of these simplifications on the outcomes of the investigation were assumed to be negligible.

Q_{OTHER}

DCW and DHW systems often need to supply water to other systems such as irrigation and mechanical air conditioning systems. These water demands (referred to as “Q_{Other}” in this report) can be significant and were therefore included in the investigation.

The flowrates for these other demands were adopted from the previous designs where available. Where flowrates were not available, they were assumed based on Lucid’s experience in similar past projects.

Q_{Other}’s were factored into the upstream PSFR_{Total}’s by assuming that the flow demand is required at the same time as the PSFR peak event.

The water demand due to the small tenancies was included in this way.

No Q_{Other} demands were required for the DHW systems.

Table 3.7 presents a list of these other demands included in the investigation:

	Description	Flowrate (L/s)
WE1	Irrigation Water (Ground Floor)	1.8
WE1	Irrigation Water (Level 20)	0.33
WE1	Café Tenancy (Ground Floor)	0.5
WE2	Cooling Tower (Roof level)	1.3
WE2	Café Tenancy 1 (Ground Floor)	0.2
WE2	Café Tenancy 2 (Ground Floor)	0.2
WE2	Café Tenancy 3 (Ground Floor)	0.2
WE2	Café Tenancy 4 (Ground Floor)	0.2
WE3	Cooling Tower (Level 2 Roof)	2
WE3	Café Tenancy	0.3
WE3	Pharmacy Tenancy	0.2
WE3	Basement Mechanical Plant	0.25
WE3	Irrigation Water (Serviced by Water Meter 2)	2

Table 3.7: List of Other Demands

PIPE SIZING

To size each pipe section, the $PSFR_{Total}$ was taken and the lowest pipe size available that complied with the nominated velocity constraints was selected. Nominal bore pipe sizes of 15mm, 20mm, 25mm, 32mm, 40mm, 50mm, 65mm, 80mm, 100mm and 150mm were used.

The maximum velocity allowed by AS3500 depends on the type of system. AS3500.1 limits DCW velocity to a maximum of 3 m/s. To limit erosion, noise, water hammer issues, cavitation, pressure surges and friction loss it is best practice to limit DCW velocity to a maximum of 1.5 m/s. This 1.5 m/s velocity constraint was adopted in this investigation for both DTS and VM systems. As this constraint was applied to both systems, the outcome of the sizing and cost comparison should not be impacted.

Maximum allowable velocities in DHW systems are stipulated in Table 1.8 of AS3500.4 for copper and non-copper pipework. The maximum velocities in AS3500.4 for copper pipework were adopted in this investigation with the exception of the deadleg value, which was reduced from 3 m/s to 1.5m/s for the same reasons as the DCW systems.

The maximum velocities used in this investigation are summarised in Table 3.8.

	Maximum Velocity (m/s)
DCW	1.5
DHW Non-Circulatory (Deadleg)	1.5
DHW Circulatory (Flow)	1.2
DHW Return Line	1

Table 3.8: Velocity Constraints

Due to the size of each development and the inclusion of a DCW pumpset in each design, pressure loss was not considered in the pipe sizing process.

3.4. BOQ AND COST ESTIMATES

For each pipe section, the length of pipe and quantity of fittings present was totalled. This data was entered into a spreadsheet. Using this information and the calculated pipe size for each pipe section, the total amount of pipework and fittings could be summarised into a bill of quantities (BOQ) for each system.

The BOQ was used with a set of assumed unit rates to reach a total cost of pipework and fittings for each system. The cost of equipment and headworks fees was then added to reach a total cost estimate for each system.

The cost associated with the supply and installation of plumbing fixtures was not included in the cost estimates, as the selection of the fixtures would not change between the DTS and VM approaches.

Designers plan drawings do not usually capture every pipe length and bend required to reticulate around on-site obstacles such as the building structure and other services. To allow for this, an additional 20% was added to the total cost of the pipe and bends to match the expected construction cost.

GROUPS AND EQUIPMENT

Certain groups of fixtures were repeated multiple times across each WE. These groups included:

- Apartments in WE1,
- Typical office floors in WE2,
- Resident rooms, dirty utilities and staff kitchenettes in WE3.

To reduce time, these groups were measured once and the results multiplied by the number of times that group of fixtures appeared. For example, if a certain apartment layout was repeated 10 times across a development; the apartment was fully measured once, and then the results multiplied by 10. As the groups were measured separately, they are presented separately in the cost estimates.

Where the sizing of plant or equipment was based on PSFR, the cost of that equipment was included in the investigation. This included DCW pumpsets, DCW break tanks, filtration and DHW re-circulation pumps. To reach cost estimates for each piece of equipment, Lucid used quotes for similar items of equipment and input from suppliers.

WE3 TMV'S

It is typical in healthcare facilities for TMV's to be built into the tapware, rather than being upstream of the fixtures. For the WE3 hospital, it was assumed all TMV's would be built into fixtures. TMV's were therefore not counted in WE3 as it was assumed their cost would be captured in the fixture cost, which was not included in this investigation.

UNIT RATES

Installation costs can vary substantially between locations and installers. To allow comparison between each WE, a set of unit rates was assumed at the start of the investigation and applied to each system. The unit rates can be found in Table 3.9 and have been based on approximate national averages from Lucid's experience in the industry. These rates include allowances for all associated costs such as material, bracketing, labour, project management and overheads.

	Pipe (\$/m)	Insulated Pipe (\$/m)	Bends (Each)	Tees (Each)	Isolation Valves (Each)	Meters (Each)	RPZD (Each)	STAD Balancing Valve (Each)	TMV (Each)
15mm	\$20.00	\$30.00	\$20.00	\$20.00	\$105.00	\$300.00	-	\$600.00	\$550.00
20mm	\$25.00	\$35.00	\$25.00	\$25.00	\$115.00	\$350.00	-	\$650.00	\$650.00
25mm	\$35.00	\$45.00	\$30.00	\$30.00	\$125.00	\$600.00	-	\$700.00	\$1100.00
32mm	\$40.00	\$50.00	\$35.00	\$45.00	\$165.00	\$1,000.00	-	\$800.00	-
40mm	\$60.00	\$70.00	\$30.00	\$40.00	\$200.00	\$1,100.00	-	-	-
50mm	\$65.00	\$75.00	\$40.00	\$50.00	\$240.00	\$1,200.00	-	-	-
65mm	\$75.00	\$85.00	\$55.00	\$65.00	\$365.00	\$1,600.00	\$2,500.00	-	-
80mm	\$115.00	\$125.00	\$80.00	\$75.00	\$460.00	\$1,700.00	\$3,500.00	-	-
100mm	\$190.00	\$210.00	\$105.00	\$95.00	\$540.00	\$3,000.00	\$4,500.00	-	-
150mm	\$350.00	\$370.00	\$273.00	\$260.00	\$650.00	\$4,000.00	\$6,000.00	-	-

Table 3.9: Unit Rates

HEADWORKS COSTS

When connecting to a water providers infrastructure, a development will usually be required to pay a headworks fee to the water provider to cover the costs associated with providing and maintaining their infrastructure. Headworks fees generally scale with the maximum flowrate required by the site and are often substantial.

Headworks fees vary considerably between states and water providers. To simplify the investigation and allow comparison between each WE, a set of headworks fees were assumed and applied to each system regardless of the water provider servicing that development. The assumed rates used in this investigation can be found in Table 3.10.

To reduce costs, techniques not stipulated in AS3500.1 are often used to justify a reduction in the required flowrate and associated headworks fees. An example of this is using a DCW storage tank to buffer the peak demand periods. To simplify the investigation these strategies were not employed, and the headworks fee was based on the full PSFR_{Total} required at the water meter in each WE.

Where WE's had multiple street connections for redundancy, the headworks fee was assumed to only apply once. This is due to the additional connection being for redundancy which would not place any additional demand on the authority infrastructure.

Connection Capacity (L/s)	Headworks Fee
0.3	\$2,000
0.7	\$5,000
1.0	\$7,000
1.3	\$9,000
2.0	\$14,000
3.0	\$21,000
3.8	\$27,000
5.7	\$39,000
7.8	\$55,000
10.0	\$70,000
12.5	\$87,000
18.3	\$128,000
25.0	\$174,000

Table 3.10: Assumed Headworks Fees

3.5. AS-BUILT SYSTEM COMPARISON

The brief required the VM sized systems to be compared to the DTS sized systems and also the as-built systems for each WE.

For all three WE's, there were minimal differences between the previous design and the as-built system.

For WE1 and WE2, the difference between the previous design and the DTS sized system used in this investigation was minimal.

For WE3, the pipework layouts used in this investigation were significantly different to the existing layouts, due to the re-designs that were required to suit this investigation.

Due to these reasons, a comparison between the as-built system and VM system would not be valuable and was not undertaken.

4. RESULTS

4.1. PSFR COMPARISON

The VM estimated lower PSFR's in almost all sections of each system. PSFR's were only increased by the VM when pipes serviced a group of fixtures which included a large proportion of showers, or where a pipe section had a low number of fixtures downstream. Where a low number of fixtures were serviced, the VM output was generally governed by Clause BV1.3(a)(i) of the VM text which generally caused a PSFR higher than the DTS approach.

The key PSFR's for each WE are presented in Table 4.1. These PSFR's have been highlighted as they had a relatively large effect on the cost of each system, due to the fact that they determine the; pipe sizing of large/long mains servicing the building, plant sizing and headworks fees. Site PSFR refers to the PSFR through the authority water meter. Primary Q_{Circ} refers to the flowrate through the recirculation pumps.

		DTS (L/S)	VM (L/S)	% Reduction due to VM
WE1 DCW	SITE PSFR (Fixtures only)	8.48	4.64	45%
WE1 DCW	SITE PSFR _{Total}	11.11	7.27	35%
WE1 DCW	PSFR _{DHWPlant}	5.6	3.56	36%
WE1 DHW	DHW Plant Outlet PSFR _{Total}	5.14	4.03	22%
WE1 DHW	Primary Q_{Circ}	0.54	0.45	17%
WE2 DCW	SITE PSFR (Fixtures only)	4.32	2.89	33%
WE2 DCW	SITE PSFR _{Total}	6.42	4.99	22%
WE2 DCW	PSFR _{DHWPlant}	2.57	1.88	27%
WE2 DHW	DHW Plant Outlet PSFR _{Total}	1.6	1.88	13%
WE2 DHW	Primary Q_{Circ}	0.15	0.15	0%
WE3 DCW	SITE PSFR (Fixtures only)	6.82	3.93	42%
WE3 DCW	Site PSFR _{Total} (Water Meter #1)	9.57	6.68	30%
WE3 DCW	Site PSFR _{Total} (Water Meter #2)	11.57	8.68	25%
WE3 DCW	DCW Loop 1 PSFR _{Total}	9.57	6.68	30%
WE3 DCW	DCW Loop 2 PSFR _{Total}	4.17	1.77	58%
WE3 DCW	DCW Loop 3 PSFR _{Total}	7.15	4.96	31%
WE3 DCW	PSFR _{DHWPlant}	5.15	2.96	43%
WE3 DHW	DHW Plant Outlet PSFR _{Total}	5.87	3.77	36%
WE3 DHW	Primary Q_{Circ}	1.67	1.43	14%

Table 4.1: Key PSFR's

Figure 4.1 to Figure 4.6 plot the $PSFR_{Total-DTS}$ against the $PSFR_{Total-VM}$ for every pipe section in each WE. A parity line has been included to assist in interpretation of the graph and represents the line where $PSFR_{Total-DTS}$ is equal to $PSFR_{Total-VM}$. Data points above the line indicate the VM increased the $PSFR_{Total}$ and data points below the line indicate the VM decreased the $PSFR_{Total}$.

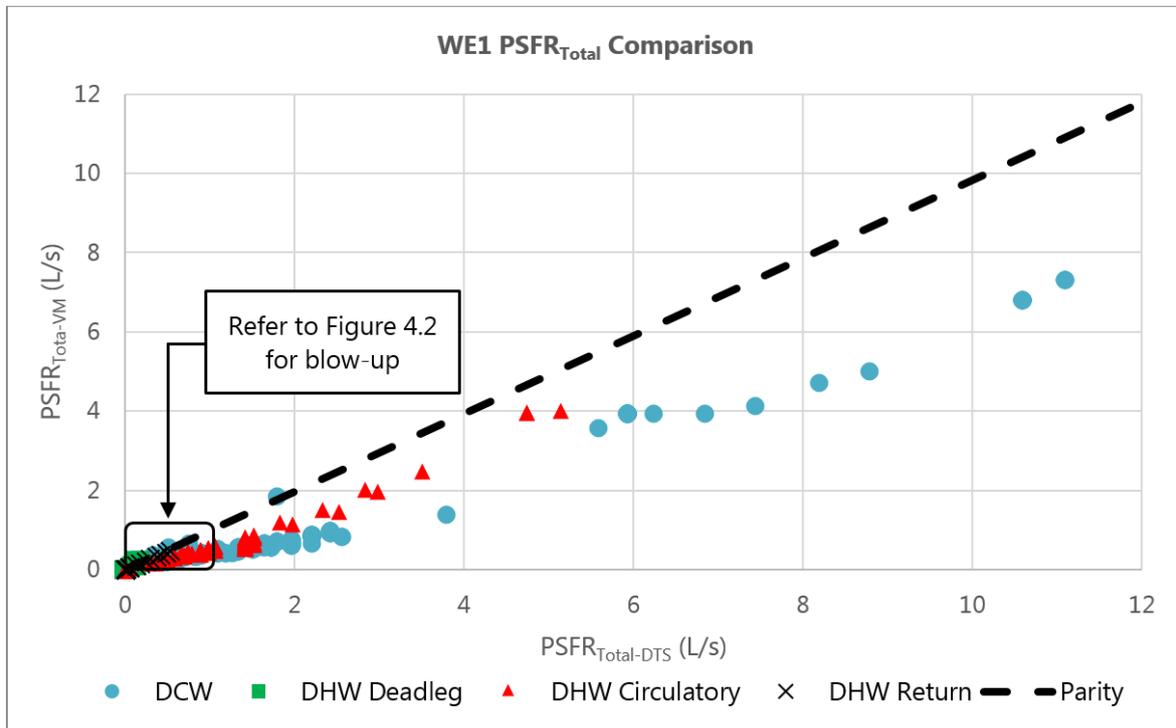


Figure 4.1: WE1 $PSFR_{Total}$ Comparison

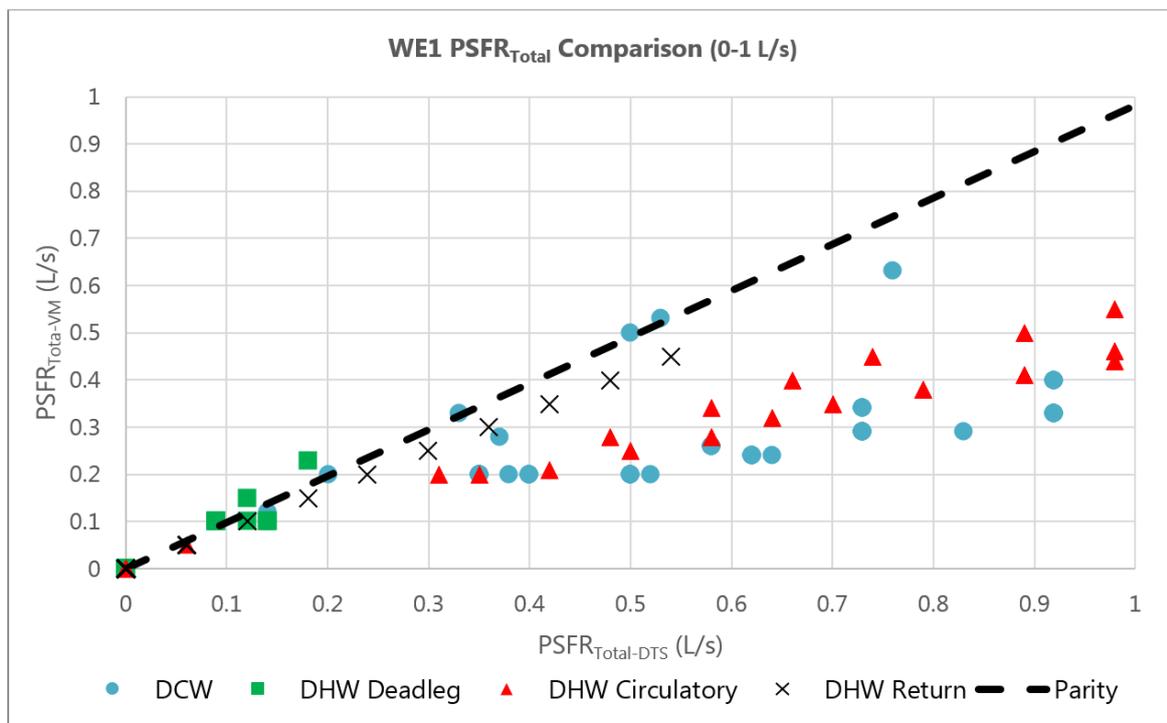


Figure 4.2: WE1 $PSFR_{Total}$ Comparison (0-1 L/s)

The VM reduced $PSFR$'s in WE1 by approximately 30-50% and the reduction was fairly consistent in all pipe sections. The only pipe sections that were increased by the VM were servicing a low number of fixtures and included at least 1 shower.

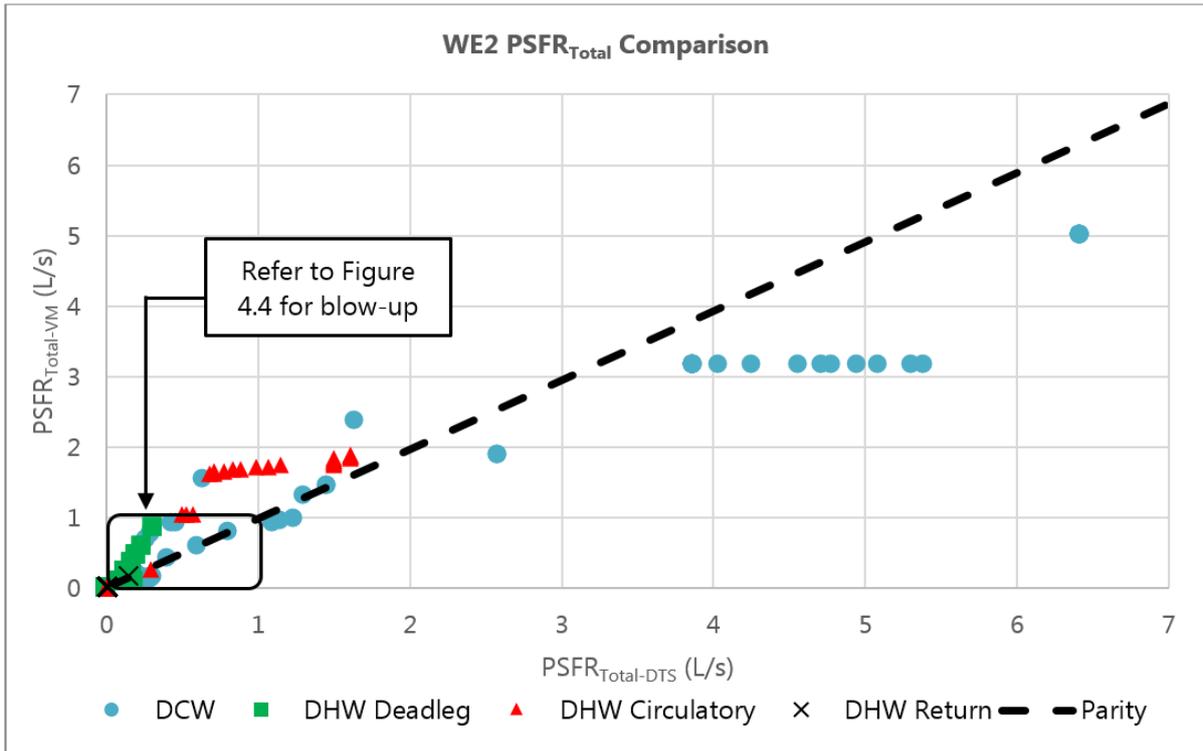


Figure 4.3: WE2 PSFR_{Total} Comparison

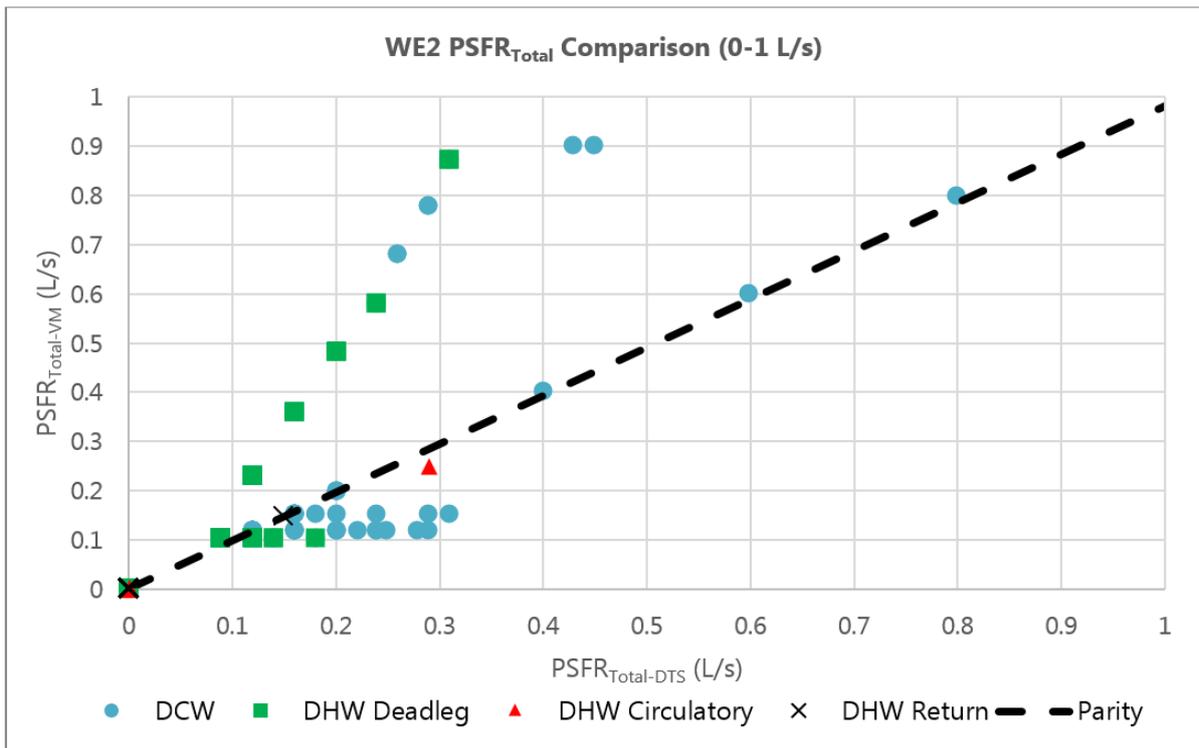


Figure 4.4: WE2 PSFR_{Total} Comparison (0-1 L/s)

The WE2 project contained an EOT trip facility on the basement level which included 14 showers. All pipe sections above the parity line were upstream of these showers. The DHW pipe sections were more affected by this increase, due to showers making up a larger proportion of the fixtures serviced by the DHW system.

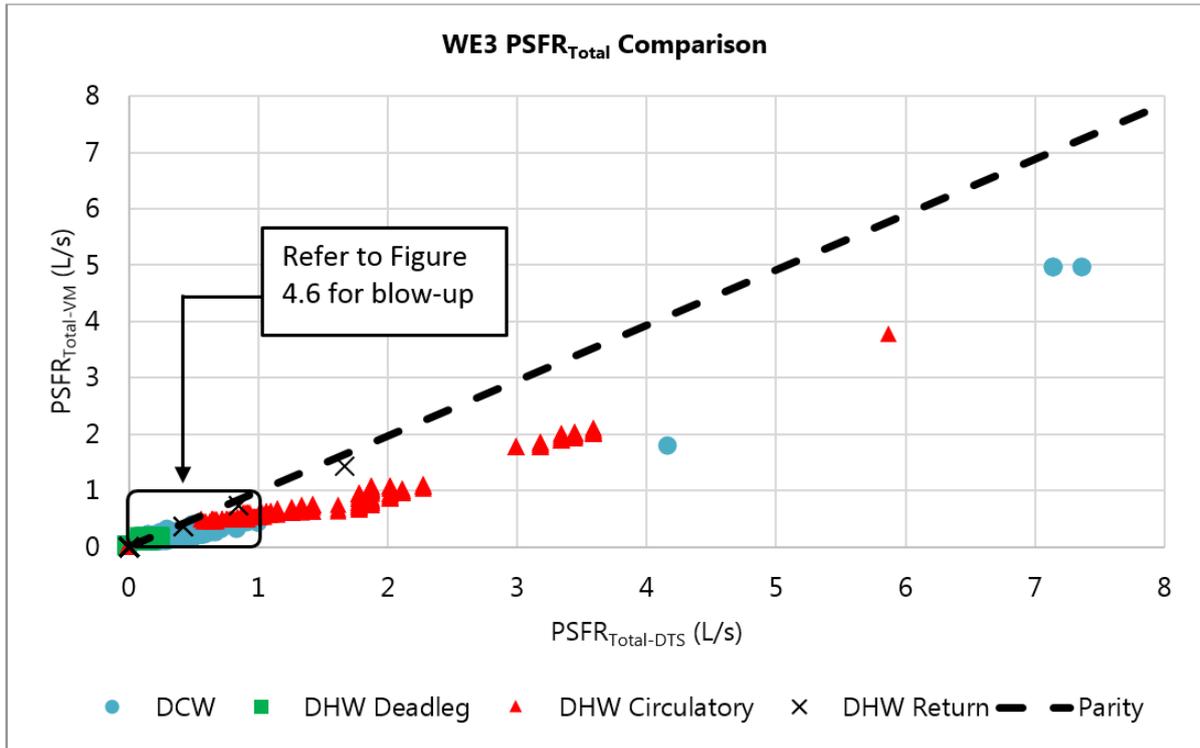


Figure 4.5: WE3 PSFR_{Total} Comparison

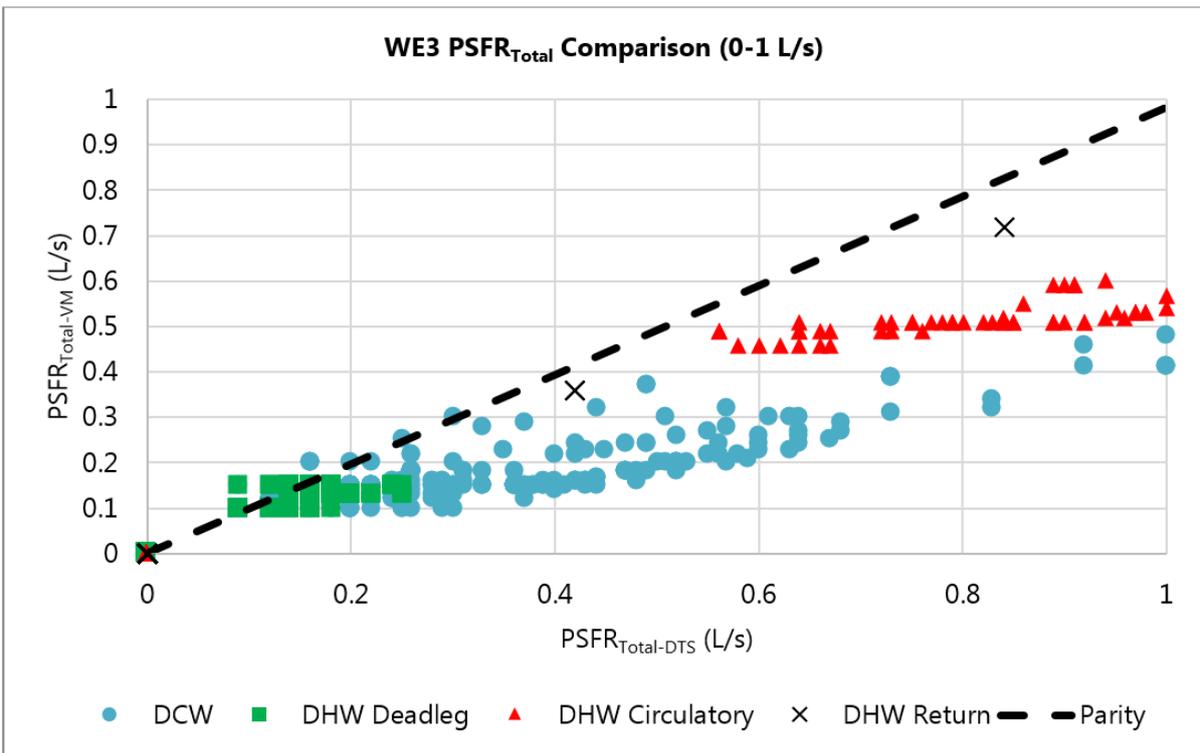


Figure 4.6: WE3 PSFR_{Total} Comparison (0-1 L/s)

PSFR's were reduced by the VM in almost all pipe sections in WE3. The VM only estimated higher PSFR's on pipe sections which serviced a low number of fixtures, and the pipe section had at least one shower downstream.

EFFECT OF SHOWERS

Showers were noted to increase the VM PSFR's significantly more than the DTS PSFR's in all three WE's. To illustrate this, Table 4.2 compares the effect of removing showers from the DTS and VM calculation for the site PSFR's due to plumbing fixtures only.

	Site PSFR (Fixtures only)	Site PSFR (Fixtures only) - All Showers removed	% Reduction
WE1 DTS	8.48	7.50	12%
WE1 VM	4.64	2.01	57%
WE2 DTS	4.32	4.17	3%
WE2 VM	2.89	1.83	37%
WE3 DTS	6.82	5.76	16%
WE3 VM	3.93	2.12	46%

Table 4.2: Effect of Showers on PSFR

This was further illustrated by the WE2 end-of-trip facilities which included 14 showers. For the DCW pipe servicing this area, the DTS method produced a PSFR_{Total} of 0.64 L/s while the VM estimated 1.53 L/s, a 239% increase. This EOT facility also caused the DHW ring main to be increased considerably by the VM, as shown in Figure 4.3.

For pipes servicing only 1 shower, each method produced different pipe sizes. For the DTS method, a shower is attributed 2 LU's. This equates to a flowrate of 0.13 L/s and a pipe size of 15mm. The VM shower flowrate for each WE was a 9 Litre per minute shower. The VM PSFR for one shower was therefore 0.15L/s due to Clause BV1.3(a)(i) of the VM text (refer to Appendix C for VM text). This results in a pipe size of 20mm pipe. This increase in pipe size had a significant effect on the costs across both DCW and DHW systems of each WE. It should be noted that this pipe size increase would not be required if a velocity of 1.62 m/s for a shower supply was deemed acceptable by the designer.

TEMPERED VM INPUTS

The DHW VM inputs for the tempered fixtures in WE1 and WE2 assumed that the fixture drew 100% DHW when operated and did not take into account the reduced demand caused by TMV's. This likely led to overly conservative VM results. To test the effect of changing the DHW VM inputs to a two-stage flowrate, a re-calculation was done on two pipe sections with revised DHW VM inputs. The revised VM inputs can be found at the end of Appendix D.

The pipe section out of the DHW plant (pipe section #1) and the pipe section immediately upstream of the end-of-trip facility (pipe section #19) were chosen.

	DTS	VM (Original)	VM (Two-Stage Inputs)
Pipe Section #1 PSFR_{Total} (L/s)	1.6	1.88	1.32
Pipe Section #19 PSFR_{Total} (L/s)	0.68	1.64	1.01

Table 4.3: Changing Tempered Inputs

As shown in Table 4.3, changing the VM DHW inputs to reflect the two-stage flowrate reduced the VM outputs by 30-40%. Even with the revised inputs, the VM still estimated the PSFR of pipe section #19 48% higher than the DTS method.

Two-stage DHW VM inputs were used in WE3 for tempered fixtures.

4.2. COST COMPARISON

Cost estimates for each WE are detailed below.

WE1

Cost estimates for WE1 are shown in Table 4.4.

	DTS	VM	% Reduction due to VM
DCW Mains	\$93,493.30	\$70,064.10	25%
DCW Groups	\$223,215.50	\$202,084.00	9%
DCW Equipment	\$75,800.00	\$52,800.00	30%
DCW Total (Excluding Headworks)	\$392,508.80	\$324,948.10	17%
Headworks Fee	\$87,000.00	\$55,000.00	37%
DCW Total (Including Headworks)	\$479,508.80	\$379,948.10	21%
DHW Mains	\$72,597.80	\$60,468.40	17%
DHW Groups	\$354,691.00	\$355,602.50	0%
DHW Equipment	\$7,400.00	\$5,500.00	26%
DHW Total	\$434,688.80	\$421,570.90	3%
Building Total	\$914,197.60	\$801,519.00	12%

Table 4.4: WE1 Cost Summary

The group components had a lower cost saving when compared to the other categories. This was due to the individual shower supplies within each apartment being increased from 15mm to 20mm by the VM. This increase offset other savings realised by the VM.

Further to this, the larger cost items in the DHW groups section such as the DHW meter, isolation valve, pressure reduction valve and TMV were the same size in both DTS and VM systems.

WE2

Cost estimates for WE2 are shown in Table 4.5.

	DTS	VM	% Reduction due to VM
DCW Mains	\$37,952.80	\$37,163.80	2%
DCW Groups	\$38,200.00	\$34,200.00	10%
DCW Equipment	\$110,152.00	\$99,320.00	10%
DCW Total (Excluding Headworks)	\$186,304.80	\$170,683.80	8%
Headworks Fee	\$55,000.00	\$39,000.00	29%
DCW Total (Including Headworks)	\$241,304.80	\$209,683.80	13%
DHW Mains	\$25,357.40	\$28,787.60	-14%
DHW Groups	\$46,934.00	\$43,670.00	7%
DHW Equipment	\$3,000.00	\$3,000.00	0%
DHW Total	\$71,798.20	\$72,114.40	0%
Building Total	\$313,103.00	\$281,798.20	10%

Table 4.5: WE2 Cost Summary

As shown in Figure 4.3, PSFR's were increased by the VM in a significant portion of DCW and DHW pipe sections. This is reflected in the WE2 cost estimates, where the mains sections were similar or increased by the VM.

Unlike the other WE's, the groups selected in WE2 did not contain any showers. This resulted in cost saving being realised in this category.

Application of the VM onto the DHW system was cost neutral, while the DCW system realised a cost saving. This was due to showers making up a considerably larger proportion of fixtures in the DHW system, when compared to the DCW system which included fixtures such as WC's and office sinks.

WE3

Cost estimates for WE3 are shown in Table 4.6.

	DTS	VM	% Reduction due to VM
DCW Mains	\$411,606.00	\$332,769.40	19%
DCW Groups	\$159,771.50	\$165,446.50	-4%
DCW Equipment	\$152,000.00	\$135,000.00	11%
DCW Total (Excluding Headworks)	\$723,377.50	\$633,215.90	12%
Headworks Fee	\$87,000.00	\$70,000.00	20%
DCW Total (Including Headworks)	\$810,377.50	\$703,215.90	13%
DHW Mains	\$309,667.60	\$273,898.80	12%
DHW Groups	\$125,292.00	\$131,295.00	-5%
DHW Equipment	\$13,500.00	\$12,000.00	11%
DHW Total	\$448,459.60	\$417,193.80	7%
Building Total	\$1,258,837.10	\$1,120,409.70	11%

Table 4.6: WE3 Cost Summary

Due to the reductions in PSFR's across WE3, a cost saving was realised in most areas. The only area where costs increased were the groups sections, which was due to the individual shower supplies being increased by the VM.

It was also noted that the DCW site $PSFR_{Total-VM}$ (ie sizing of street connections, basement plant and Loop 1) was only slightly above the threshold to increase to 100mm. If, for example, a cooling tower make-up flowrate of 1.5 L/s had been assumed rather than the 2 L/s, an additional cost saving of \$40,000 would have been realised from approximately 550m of pipework being reduced from 100mm to 80mm in diameter. An alternative way of viewing this is that the street connections and Loop 1 for the VM system have a considerably larger capacity for future connections than the DTS ring mains.

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APPENDIX A: DEFINITION OF TERMS

Terms used in this report generally followed the definitions in AS/NZS 3500.0:2003. Other terms used in this report are defined below.

Term	Explanation
Bill of Quantities (BOQ)	A breakdown of costs into measured quantities of materials, equipment and labour required to install the works described.
Designer	The person or organisation designing the DCW system and are responsible for deciding pipework routing and sizing.
Domestic Cold Water (DCW)	Potable water that has not been intentionally heated.
Domestic Hot Water (DHW)	Potable water that has been intentionally heated and is stored & reticulated at least 60 degrees Celsius.
Deemed to Satisfy (DTS)	In this report, refers to the prescriptive requirements of AS/NZS 3500.1:2015.
Headworks Fees	Fees paid to Water Provider, when connecting to street infrastructure, to cover the costs associated with providing and maintaining their infrastructure.
Loading Unit (LU)	A number applied to each type of plumbing fixture, that is used in estimating PSFR. Number is based on the plumbing's fixtures flow rate and usage characteristics.
Plan Layouts	Drawings showing pathways pipework is running, in plan view.
Probable Simultaneous Flow Rate (PSFR)	Plan layouts aim to capture all pipework required to complete installation, including offsets around structure.
PSFR _{DTS}	The probable maximum flowrate through a section of pipe, based on the demands downstream of that pipe. Calculated using a probability-based method.
PSFR _{DHWPlant}	PSFR for a section of pipe calculated using the DTS method. Refers to the demand from either plumbing fixtures only (doesn't include Q _{Other} or Q _{Circ}).
PSFR _{Total-DTS} or PSFR _{Total-VM}	Probable Simultaneous Flow Rate in that section of cold water pipe, due to hot water plant demand only.
PSFR _{VM}	Probable Simultaneous Flow Rate for that section of pipe, due to all demands for either the DTS or VM approach,
Q _{Circ}	PSFR for a section of pipe calculated using the VM method. Refers to the demand from plumbing fixtures only (doesn't include Q _{Other} or Q _{Circ}).
Q _{Other}	The flowrate in that section of pipe due to forced DHW re-circulation. Only applicable in DHW circulatory or return pipes.

Term	Explanation
Verification Method (VM)	In this report, refers to demands on the DCW system that are not due to plumbing fixtures cold or $PSFR_{DHWPlant}$ demands. Examples include irrigation, mechanical make-up water or assumed loads from tenancies.
Worked Example (WE)	Generally refers to a method for assessing whether a performance solution complies with the relevant performance requirements of the NCC. In this report, the verification method refer to a specific method developed by the ABCB, for estimating PSFR's in a cold water system.
Water Efficiency Labelling and Standards Scheme (WELS)	A previous project that Lucid been involved in, which will be re-sized using both the DTS and VM approaches.

APPENDIX B: LOADING UNIT CONVERSION TABLE

The table below provides the complete LU conversion table used in this investigation. Deadleg PSFR's for LU from 1-60 are taken from AS/NZS 3500.1:2018 Table 3.2.4. Deadleg PSFR's for LU above 60 are taken from "Selection and Sizing of Copper Tubes for Water Piping Systems" (Smith 1976). Circulatory PSFR's for LU totals between 1-100 are taken from AS/NZS 3500.1:2018 Table 3.2.4. Circulatory PSFR's for LU totals above 100 are taken from AS/NZS 3500.4:2018 Appendix O.

Loading Units	Deadleg PSFR (L/s)	Circulatory PSFR (L/s)	Loading Units	Deadleg PSFR (L/s)	Circulatory PSFR (L/s)
1	0.09	0.09	26	0.43	0.43
2	0.12	0.12	27	0.44	0.44
3	0.14	0.14	28	0.45	0.45
4	0.16	0.16	29	0.46	0.46
5	0.18	0.18	30	0.47	0.47
6	0.2	0.2	31	0.48	0.48
7	0.22	0.22	32	0.49	0.49
8	0.24	0.24	33	0.49	0.49
9	0.25	0.25	34	0.5	0.5
10	0.26	0.26	35	0.51	0.51
11	0.28	0.28	36	0.52	0.52
12	0.29	0.29	37	0.52	0.52
13	0.3	0.3	38	0.53	0.53
14	0.31	0.31	39	0.54	0.54
15	0.33	0.33	40	0.55	0.55
16	0.34	0.34	41	0.55	0.55
17	0.35	0.35	42	0.56	0.56
18	0.36	0.36	43	0.57	0.57
19	0.37	0.37	44	0.58	0.58
20	0.38	0.38	45	0.58	0.58
21	0.39	0.39	46	0.59	0.59
22	0.4	0.4	47	0.6	0.6
23	0.41	0.41	48	0.6	0.6
24	0.42	0.42	49	0.61	0.61
25	0.43	0.43	50	0.62	0.62

Loading Units	Deadleg PSFR (L/s)	Circulatory PSFR (L/s)	Loading Units	Deadleg PSFR (L/s)	Circulatory PSFR (L/s)
51	0.62	0.62	360	2.57	-
52	0.63	0.63	400	2.73	2
53	0.64	0.64	440	2.95	-
54	0.64	0.64	450	-	2.15
55	0.65	0.65	480	3.1	-
56	0.65	0.65	500	-	2.35
57	0.66	0.66	520	3.26	-
58	0.67	0.67	550	-	2.5
59	0.67	0.67	560	3.41	-
60	0.68	0.68	600	3.48	2.6
70	0.73	-	640	3.64	-
80	0.83	-	650	-	2.75
90	0.92	-	680	3.79	-
100	1	1.2	700	-	2.85
110	1.1	-	720	3.86	-
120	1.2	-	750	-	2.95
130	1.27	-	760	4.01	-
140	1.35	-	800	4.09	3.05
150	1.42	1.35	840	4.17	-
160	1.5	-	850	-	3.2
170	1.57	-	880	4.32	-
180	1.65	-	900	-	3.3
190	1.72	-	920	4.39	-
200	1.8	1.45	950	-	3.4
240	1.97	-	960	4.47	-
250	-	1.6	1000	4.54	4.6
280	2.2	-	1040	4.7	-
300	-	1.7	1080	4.77	-
320	2.42	-	1120	4.85	-
350	-	1.85	1160	5	-

Loading Units	Deadleg PSFR (L/s)	Circulatory PSFR (L/s)	Loading Units	Deadleg PSFR (L/s)	Circulatory PSFR (L/s)
1200	5.07	3.8	2400	7.88	5.75
1240	5.15	-	2440	7.95	-
1280	5.23	-	2480	8.03	-
1320	5.38	-	2520	8.18	-
1360	5.45	-	2560	8.25	-
1400	5.53	4.2	2600	8.33	6
1440	5.6	-	2640	8.48	-
1480	5.68	-	2680	8.56	-
1520	5.76	-	2720	8.63	-
1560	5.91	-	2760	8.71	-
1600	5.98	4.6	2800	8.78	-
1640	6.06	-	2840	8.94	-
1680	6.13	-	2800	9.01	-
1720	6.29	-	2920	9.09	-
1760	6.36	-	2960	9.24	-
1800	6.44	4.9	3000	9.31	6.7
1840	6.51	-	3040	9.39	-
1880	6.66	-	3080	9.47	-
1920	6.74	-	3120	9.54	-
1960	6.82	-	3160	9.69	-
2000	6.89	5.25	3200	9.77	-
2040	7.04	-	3240	9.84	-
2080	7.12	-	3280	9.92	-
2120	7.19	-	3320	10	-
2160	7.27	-	3360	10.15	-
2200	7.42	5.5	3400	10.22	-
2240	7.5	-	3440	10.3	-
2280	7.57	-	3480	10.45	-
2320	7.65	-	3500	7.25	-
2360	7.8	-	3520	10.53	-

Loading Units	Deadleg PSFR (L/s)	Circulatory PSFR (L/s)	Loading Units	Deadleg PSFR (L/s)	Circulatory PSFR (L/s)
3560	10.6	-			
3600	10.68	-			
3640	10.83	-			
3680	10.91	-			
3720	10.98	-			
3760	11.06	-			
3800	11.13	-			
3840	11.28	-			
3880	11.36	-			
3920	11.44	-			
3960	11.51	-			
4000	11.66	7.75			

APPENDIX C: VM DRAFT TEXT

BV1.3 - Determination of probable simultaneous flow rate using probability analysis

(a) Steps for using this *Verification Method*

Compliance with *Performance Requirement BP1.2(b)* is verified for each cold water system when—

- (i) the design flow rate in all pipework sections is not less than—
 - (A) the probable simultaneous flow rate calculated in accordance with **(b)**; or
 - (B) the flow rate of the single fixture with the largest flow rate downstream of the pipework section,
 whichever is the greater; and
- (ii) the water velocity in the pipework is not more than 3.0 m/s; and
- (iii) the water pressure at any outlet is not more than 500 kPa and not less than—
 - (A) 50 kPa; or
 - (B) the minimum pressure required by the fixture to function,
 whichever is the greater.

(b) Determination of the probable simultaneous flow rate

For each pipework section, the probable simultaneous flow rate must be calculated in accordance with the following:

$$PSFR = \sum_{k=1}^K \frac{n_k t_k q_k}{T_k} + z_{99} \sqrt{\sum_{k=1}^K \frac{n_k t_k q_k^2 (T_k - t_k)}{T_k^2}}$$

where—

- $n_{1, 2, \text{etc}}$ = the total number of fixtures or supply openings of a given type downstream of the pipework section; and
- $t_{1, 2, \text{etc}}$ = the average duration of flow in seconds for a given fixture type for one use; and
- $T_{1, 2, \text{etc}}$ = the average time in seconds between successive operations of any given fixture of a particular type, during the period of expected maximum usage frequency; and
- $q_{1, 2, \text{etc}}$ = the operating flowrate of a single fixture of a given type; and
- K = the number of different fixture types downstream of the pipework section; and
- = the z-score for the 99th percentile of flow rate, equal to 2.326; and
- PSFR = the probable simultaneous flow rate in the pipework section.

APPENDIX D: VM CALCULATOR INPUTS

WE1: RESIDENTIAL PEAK

Fixture	The average duration of flow in seconds for a given fixture type for one use (s)	The average time in seconds between successive operations of any given fixture of a particular type, during the period of expected maximum usage frequency (s)	Operating flowrate of a single fixture of a given type (L/s)	Notes
WC (Apartment)	30	3,600 (1 hour)	0.12	WELS 4-star WC (architectural schedule).
WC (Common Area)	30	1,200 (20 minutes)	0.12	WELS 4-star WC (architectural schedule).
Basin (Apartment)	15	1,800 (30 minutes)	0.10	WELS 5-star basin tapware (architectural schedule).
Basin (Common Areas)	5	1,200 (20 minutes)	0.10	WELS 5-star basin tapware (architectural schedule).
Shower (Apartment)	480	7,200 (2 hours)	0.15	WELS 3-star shower (architectural schedule).
Shower (Common Area)	480	1,800 (30 minutes)	0.15	WELS 3-star shower (architectural schedule).
Kitchen Sink (Apartment)	60	7,200 (2 Hours)	0.10	WELS 5-star mixer (architectural schedule).
Kitchen Sink (Common Area)	20	1,200 (20 minutes)	0.10	WELS 5-star mixer (architectural schedule).
Dishwasher (Apartment)	60	14,400 (4 Hours)	0.20	Selection from architectural schedule + associated technical data.
Dishwasher (Common Area)	60	72,000 (20 Hours)	0.20	Selection from architectural schedule + associated technical data.
Washing Machine (Apartment)	13000	14,400 (4 Hours)	0.05	Selection from architectural schedule + associated technical data.
Hose Tap (Common Area)	20	21,600 (6 Hours)	0.20	Assumed.

Laundry Trough (Apartment)	120	72,000 (20 hours)	0.15	Assumed.
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WE1: LEVEL 20 COMMON AREA PEAK

Fixture	The average duration of flow in seconds for a given fixture type for one use (s)	The average time in seconds between successive operations of any given fixture of a particular type, during the period of expected maximum usage frequency (s)	Operating flowrate of a single fixture of a given type (L/s)	Notes
WC (Common Area)	30	1,200 (20 minutes)	0.12	WELS 4-star WC (architectural schedule).
Basin (Common Areas)	5	1,200 (20 minutes)	0.10	WELS 5-star basin tapware (architectural schedule).
Shower (Common Area)	480	1,200 (20 minutes)	0.15	WELS 3-star shower (architectural schedule).
Kitchen Sink (Common Area)	60	1,800 (30 minutes)	0.10	WELS 5-star mixer (architectural schedule).
Dishwasher (Common Area)	60	10,800 (3 Hours)	0.20	Selection from architectural schedule + associated technical data.
Hose Tap (Common Area)	300	21,600 (6 Hours)	0.20	Assumed.

WE1: Ground Floor Café DHW (Morning Peak)

Fixture	The average duration of flow in seconds for a given fixture type for one use (s)	The average time in seconds between successive operations of any given fixture of a particular type, during the period of expected maximum usage frequency (s)	Operating flowrate of a single fixture of a given type (L/s)	Notes
Basin DHW(Café)	5	600 (10 minutes)	0.10	WELS 5-star basin tapware (assumed)
Sink DHW (Café)	30	1,200 (20 minutes)	0.15	WELS 3-star mixer (assumed)

WE2: COMMON AREAS/EOT (8AM-10AM WEEKDAY)

Fixture	The average duration of flow in seconds for a given fixture type for one use (s)	The average time in seconds between successive operations of any given fixture of a particular type, during the period of expected maximum usage frequency (s)	Operating flowrate of a single fixture of a given type (L/s)	Notes
WC (Common Area)	30	900 (15 Minutes)	0.12	Assumed WELS 4-star cistern.
Urinal (Common Area)	15	600 (10 minutes)	0.12	Assumed WELS 4-star cistern.
Basins (Common Area)	5	300 (5 minutes)	0.10	Assumed WELS 5-star basin tapware.
Shower (Common Area)	480	1,200 (20 minutes)	0.15	Assumed WELS 3-star shower.
Cleaners Sink (Common Area)	60	14,400 (4 hours)	0.15	Assumed WELS 3-star.
Hose Tap (Common Area)	20	36,000 (10 Hours)	0.15	Assumed.
Kitchen Sink (Office)	20	1,200 (20 Minutes)	0.13	Assumed WELS 5-star mixer.
Dishwasher (Office)	60	14,400 (4 hours)	0.15	Typical Domestic-type dishwasher assumed. No DHW connection.
Boiling Water Unit (Office)	5	180 (3 Minutes)	0.02	Typical below bench unit assumed.

WE2: CAFE (8-10AM WEEKDAY)

Fixture	The average duration of flow in seconds for a given fixture type for one use (s)	The average time in seconds between successive operations of any given fixture of a particular type, during the period of expected maximum usage frequency (s)	Operating flowrate of a single fixture of a given type (L/s)	Notes
Basin (Café)	5	600 (10 minutes)	0.10	WELS 5-star basin tapware (assumed)
Sink (Café)	30	1,200 (20 minutes)	0.15	WELS 3-star mixer (assumed)

WE2: COMMON AREAS/EOT – STAGED TEMPERED FLOWRATES (8AM-10AM WEEKDAY)

The following inputs were not used in the WE2 investigation but were used to test the effects of changing the certain VM inputs to reflect the “two stage” flowrates profile caused by TMV’s.

Fixture	The average duration of flow in seconds for a given fixture type for one use (s)	The average time in seconds between successive operations of any given fixture of a particular type, during the period of expected maximum usage frequency (s)	Operating flowrate of a single fixture of a given type (L/s)	Notes
Basins (Common Area) (Stage 1)	5	300 (5 minutes)	0.10	Assumed WELS 5-star basin tapware.
Basins (Common Area) (Stage 2)	5	900 (15 minutes)	0.06	Assumed WELS 5-star basin tapware.
Shower (Common Area) (Stage 1)	5	1,200 (20 minutes)	0.15	Assumed WELS 3-star shower.
Shower (Common Area) (Stage 2)	475	1,200 (20 minutes)	0.10	Assumed WELS 3-star shower.
Cleaners Sink (Common Area)	60	14,400 (4 hours)	0.15	Assumed WELS 3-star.

WE3

Fixture	The average duration of flow in seconds for a given fixture type for one use (s)	The average time in seconds between successive operations of any given fixture of a particular type, during the period of expected maximum usage frequency (s)	Operating flowrate of a single fixture of a given type (L/s)	Notes on average duration and operating flowrate.
WC (Resident Room)	30	7,200 (2 hours)	0.12	Assumed WELS 4-star cistern.
Basins (Resident Room)	5	1,800 (30 minutes)	0.10	Assumed WELS 5-star basin tapware.
Shower (Resident Room)	480	14,400 (4 hours)	0.15	Assumed WELS 3 star rated shower mixer.
WC (Common Area)	30	1,800 (30 minutes)	0.12	Assumed WELS 4-star cistern.
Basins (Common Area)	5	900 (15 minutes)	0.10	Assumed WELS 5-star basin tapware.
Shower (Common Area)	480	3,600 (1 hour)	0.15	Assumed WELS 3 star.
Sink (Tea Prep)	20	1,800 (30 minutes)	0.13	Assumed WELS 4-star sink tapware.
Dishwasher (Tea Prep)	60	14,400 (4 hours)	0.15	Assumed based on typical domestic type dishwasher.
Boiling Water Unit (Tea Prep)	5	1,200 (20 minutes)	0.01	Assumed based on typical below bench boiling water unit with sink mounted dispenser.
Cleaners Sink (Dirty Utility/Cleaners Room)	60	7,200 (2 hours)	0.13	Assumed WELS 4-star sink tapware.
Basins (Dirty Utility/Cleaners Room)	5	7,200 (2 hours)	0.10	Assumed WELS 5-star basin tapware.
Sink (Flushing Rim)	30	1,200 (20 minutes)	0.12	Assumed WELS 4-star cistern.
Macerator	120	1,200 (20 minutes)	0.20	Assumed based on typical macerator tech data.
Slop Hopper	30	1,200 (20 minutes)	0.12	Assumed WELS 4-star cistern.
Sink (Scrub Sink)	30	900 (15 minutes)	0.13	Assumed WELS 4-star sink tapware.

Sink (Commercial Kitchen)	60	1,200 (20 minutes)	0.13	Assumed WELS 4-star sink tapware.
Dishwasher (Commercial Kitchen)	60	1,200 (20 minutes)	0.15	Assumed based on typical commercial pass through dishwasher/glasswasher tech data
Basins (Commercial Kitchen)	5	600 (10 minutes)	0.10	Assumed WELS 5-star basin tapware.
SNBC	300	36,000 (10 hours)	0.20	Assumed.
Bath/Spa	1200	18,000 (5 hours)	0.15	Assumed WELS 3-star tapware.

WE2: STAGED TEMPERED FIXTURES

The below inputs were not used in the DHW investigation but were used in the tempered fixtures comparison on page 28.

Fixture	The average duration of flow in seconds for a given fixture type for one use (s)	The average time in seconds between successive operations of any given fixture of a particular type, during the period of expected maximum usage frequency (s)	Operating flowrate of a single fixture of a given type (L/s)	Notes on average duration and operating flowrate.
Basins (Resident Room) (Stage 1)	5	1,800 (30 minutes)	0.10	Assumed WELS 5-star basin tapware.
Basins (Resident Room) (Stage 2)	5	3,600 (60 minutes)	0.06	Assumed WELS 5-star basin tapware.
Shower (Resident Room) (Stage 1)	5	14,400 (4 hours)	0.15	Assumed WELS 3 star rated shower mixer.
Shower (Resident Room) (Stage 2)	475	14,400 (4 hours)	0.10	Assumed WELS 3 star rated shower mixer.
Basins (Common Area) (Stage 1)	5	900 (15 minutes)	0.10	Assumed WELS 5-star basin tapware.
Basins (Common Area) (Stage 2)	5	1800 (30 minutes)	0.06	Assumed WELS 5-star basin tapware.
Shower (Common Area) (Stage 1)	5	3,600 (1 hour)	0.15	Assumed WELS 3 star.

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Shower (Common Area) (Stage 2)	475	3,600 (1 hour)	0.10	Assumed WELS 3 star.
Basins (Dirty Utility/Cleaners Room) (Stage 1)	5	7,200 (2 hours)	0.10	Assumed WELS 5-star basin tapware.
Basins (Dirty Utility/Cleaners Room) (Stage 2)	5	14,400 (4 hours)	0.06	Assumed WELS 5-star basin tapware.
Basins (Commercial Kitchen) (Stage 1)	5	600 (10 minutes)	0.10	Assumed WELS 5-star basin tapware.
Basins (Commercial Kitchen) (Stage 2)	5	1,200 (20 minutes)	0.10	Assumed WELS 5-star basin tapware.
Bath/Spa (Stage 1)	5	18,000 (5 hours)	0.15	Assumed WELS 3-star tapware.
Bath/Spa (Stage 2)	1200	18,000 (5 hours)	0.15	Assumed WELS 3-star tapware.

APPENDIX E: EXAMPLE VM CALCULATOR OUTPUT

The following is a screenshot of the VM calculator output for the site PSFR_{Total-VM} of WE1:

ABCB Flow Rate Calculator - Testing Draft
For the determination of Probable Simultaneous Flow Rate in accordance with the draft text of BV1.3

Result - 99th Percentile PSFR (l/s)
4.64

Input Data				
Fixture type	Total number of fixtures	Average duration of flow for one use of a given fixture (s)	Time between successive operations of a given fixture (s)	Flow rate per fixture (l/s)
Basins (Apartment)	192	15	1800	0.1
Shower (Apartment)	192	480	7200	0.15
WC (Apartment)	192	30	3600	0.12
Kitchen Sink (Apartment)	136	60	7200	0.1
Dishwasher (Apartment)	136	60	14400	0.2
Washing Machine (Apartment)	136	1300	14400	0.05
Laundry Trough (Apartment)	136	120	72000	0.15
Basins (Common Area)	4	5	1200	0.1
Shower (Common Area)	1	480	1800	0.15
WC (Common Area)	4	30	1200	0.12
Kitchen Sink (Common Area)	2	20	1200	0.1
Dishwasher (Common Area)	1	60	72000	0.2
Hose Tap	2	20	21600	0.2