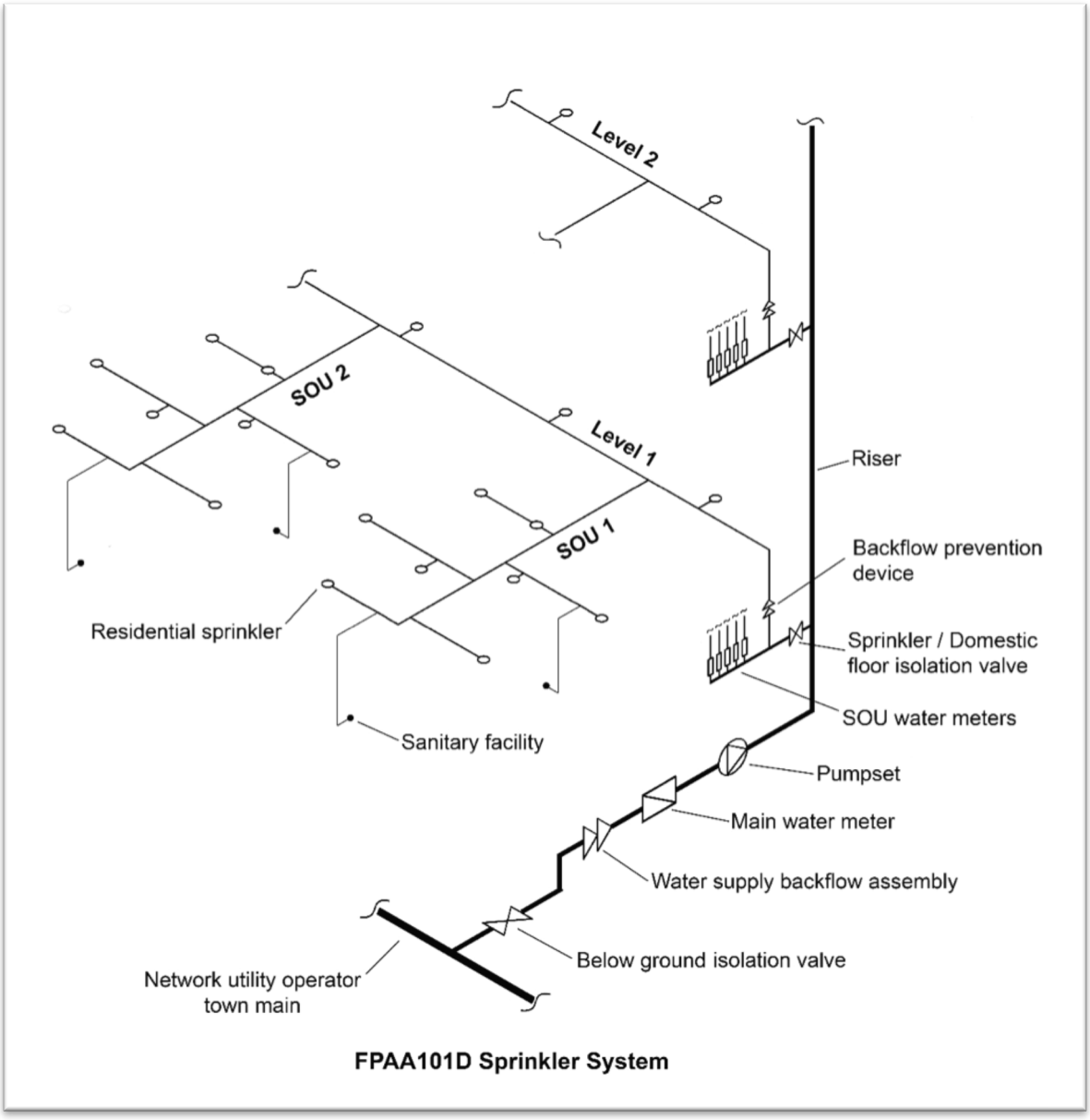
Water quality risk assessment of the FPAA101D Specification fire sprinkler system



Review of health and aesthetic water quality risks associated with the introduction of combination domestic fire sprinkler systems that directly connect to potable water plumbing systems in residential buildings of less than 25 m metres in height. Document dated 17th October 2018.

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1 Document history

Document name	Version number	Document authors	Document reviewer	Date of version
Water quality risk assessment of the FPAA101D Specification fire sprinkler system	Version 1	Dan Deere	Mark Whybro	6th October 2018
	Version 2	Dan Deere	Mark Whybro and stakeholders	7th October 2018
	Version 3	Dan Deere	Mark Whybro and stakeholders	16th October 2018
	Version 4	Dan Deere	Mark Whybro and stakeholders	17th October 2018

2 Acronyms

Abbreviation	Meaning
ABCB	Australian Building Codes Board
ADWG	Australian Drinking Water Guidelines
AFAC	Australasian Fire and Emergency Service Authorities Council
AHPPC	Australian Health Protection Principal Committee
BPAA	Backflow Prevention Association of Australia
BETG	Built Environment Technical Group
EnHealth	Environmental Health Standing Committee
FPA Australia	Fire Protection Association Australia
FRNSW	Fire and Rescue NSW
NCC	National Construction Code
PCC	Plumbing Codes Committee
PFC	Proposal For Change
QMRA	Quantitative microbial risk assessment
TRA	Toxicological risk assessment

3 Executive summary

3.1 Purpose

The purpose of this review was to provide an independent, evidence-based and referenced report that assesses the proposed new residential sprinkler design as set out in the Fire Protection Association (FPA) Australia's Technical Specifications "FPAA101D Automatic Fire Sprinkler System Design and Installation – Domestic Water Supply" (draft at the time of writing). The review was undertaken by an independent drinking water quality specialist experienced in assessing risks arising in buildings from plumbing systems with more than one plumbing system (e.g. plumbing for recycled, irrigation, process, flushing and deadleg waters).

3.2 Context

The FPAA101D Specification responds to a joint Proposal for Change (PFC) from FPA Australia, Fire and Rescue NSW (FRNSW) and Australasian Fire and Emergency Service Authorities Council (AFAC) to the 2019 National Construction Code (NCC), which seeks to mandate sprinklers in Class 2 and 3 Sole Occupancy Units and common areas in residential accommodation in buildings less than 25 m metres in height.

The proposed change will allow "Combination Domestic Fire Sprinkler Systems" for such buildings to have their sprinklers directly connected to the domestic water supply plumbing rather than being fed by a fully separate firefighting plumbing system. For such Combination Domestic Fire Sprinkler Systems, the PFC proponents consider that it will not be necessary to install testable backflow prevention devices on the water supply plumbing directly feeding the sprinklers. The sprinklers will be fed from plumbing supply lines that feed other parts of the property and will often be very short and, as such, the FPAA101D Specification requires non-testable dual check valve backflow protection but will not require testable backflow prevention devices on the feeds to the sprinkler plumbing for each individual sprinkler feed line. Due to this difference between testable and non-testable devices, backflow risks have been singled out for detailed analysis in this report.

3.3 Approach

The assessment identifies and considers relevant contaminants (e.g. pathogens and toxicants) and assesses events that may present risks to drinking water quality (e.g. backflow, cross-connection, diffusion or inhalation) from implementing the FPAA101D Specification. The assessment compared risks with benchmarks of water quality protection as set out in Australia's existing plumbing, building and drinking water quality guidelines and standards as they relate to public health, aesthetic quality and public safety. The assessment commented on relative risks. For instance, many of the water quality risks relate to relatively low risk aesthetic considerations whereas the objective of a fire suppression system is to protect from the foreseeable high risk of death and serious injury from fire. In addition, risks relating to the proposed FPAA101D Specification were compared to risks associated with current plumbing standards and extant plumbing systems.

3.4 Stakeholders

Parties interested in the findings of this assessment include the above-mentioned proponents of the FPAA101D Specification (AFAC, FPA Australia and FRNSW) as well as the Australian Building Codes Board (ABCB), Plumbing Codes Committee (PCC), Built Environment Technical Group (BETG), Backflow Prevention Association of Australia (BPAA), Queensland Health, WA Building and Energy, Plumbing Technical Reference Group, and the Environmental Health Standing Committee (enHealth) of the Australian Health Protection Principal Committee (AHPPC). In addition, water utilities, plumbing regulators and inspectors may have an interest. The assessment was presented with those informed expert parties in mind, not for the general public or laypersons.

3.5 Summary of principal findings

For the convenience of readers, the principal findings arising from the assessment are summarised as follows. Further details discussing these findings are given in the body of the report.

3.5.1 Risks to human health from enteric pathogens

Implementing the FPAA101D Specification was not considered to present elevated risks from enteric pathogens[1] when compared to existing plumbing standards. Significant risks were not identified due to the proposed FPAA101D Specification and risks were not considered to be elevated relative to risks associated with existing plumbing standards. The principal reason for this conclusion was that deadlegs are not sources of enteric pathogens, which are faecal-oral in their transmission pathways.

3.5.2 Risks to human health from opportunistic pathogens

Although implementing the FPAA101D Specification was considered to present a potential risk from opportunistic pathogens[2], importantly, when compared to existing plumbing standards, the risk was similar to, or at worst only marginally and incrementally elevated, relative to existing standards. The FPAA101D Specification did not present a step change increase in risk since no new broad categories or classes of hazards or risks were introduced. The potentially incremental increase in risk was related to the presence of fire sprinkler system deadlegs protected from the potable water supply by a non-testable dual check valve. This risk compares to plumbing systems that either lacked fire sprinkler systems and the associated deadlegs, or that had conventional fire sprinkler systems including deadlegs charged by a separate fire service from which the potable system is protected by a testable backflow prevention device. In the latter case it was noted that conventional fire sprinkler systems would be expected to present a greater total volume of deadleg due to the greater total volume of water in the fire service plumbing system as a whole. It was noted that deadlegs are already commonplace in buildings due to seldom used or abandoned taps and fittings and most

[1] In this context, enteric pathogens are microorganisms that cause gastrointestinal illness, such as diarrhoea and vomiting, as a part of their normal life cycle, e.g. *Salmonella* and *Giardia*. Where they become waterborne they are passed due to faecal contamination of water that is then ingested.

[2] In this context, opportunistic pathogens are microorganisms that do not normally cause illness and live naturally in water at low levels but that can cause illness under certain circumstances if they reach high enough levels in stagnant water lacking in a disinfectant residual, e.g. *Legionella* and *Naegleria*.

have no form of backflow protection within the building. These risks were considered in more depth within the body of this report and are discussed again within this Executive Summary at section 3.6.

3.5.3 Risks to human health from toxicants

Although implementing the FPAA101D Specification was considered to present a potential risk associated with chemical toxicants[3], importantly, when compared to existing plumbing standards, the risk was similar to, or at worst only marginally and incrementally elevated, relative to existing standards. The FPAA101D Specification did not present a step change increase in risk since no new broad categories or classes of risks were introduced. Any potentially incrementally increased risk was considered to be insignificant on the grounds that to be hazardous to health chemicals either need to be acutely toxic at levels that can be ingested without being discernible, or need to be consumed over long periods. Reasonably foreseeable scenarios by which chemical toxicants that had built up to hazardous concentrations in deadlegs would reach potable water fittings would be expected to be rare, sporadic, short-lived and typically self-evident and self-limiting due to the discernibly poor aesthetic quality of stagnant water. Furthermore, unlike conventional fire sprinkler systems, the FPAA101D Specification required WaterMark potable water grade plumbing lines and fittings to be used.

3.5.4 Risks to human perception from poor aesthetic water quality

Although implementing the FPAA101D Specification was considered to present a potential risk associated with poor aesthetic water quality[4], importantly, when compared to existing plumbing standards, the risk was similar to, or at worst only marginally and incrementally elevated, relative to existing standards. The FPAA101D Specification did not present a step change increase in risk since no new broad categories or classes of risks were introduced. Any potentially incrementally increased risk was considered to be insignificant because poor aesthetic water quality arising under rare, sporadic, short-lived scenarios would be likely to be considered acceptable given the overwhelming and self-evident benefits of having a fire sprinkler system where one might otherwise not be. In addition, such events would be readily mitigated by simply flushing the water for a very short period given the limitations placed on the lengths of deadlegs within the FPAA101D Specification. Furthermore, unlike conventional fire sprinkler systems, the FPAA101D Specification required WaterMark potable water grade plumbing lines and fittings to be used.

3.5.5 Conclusions

The FPAA101D Specification presents no increase in risk associated with enteric pathogens relative to existing plumbing standards.

The FPAA101D Specification presents at worst an incremental, but not a step change, increase in risks associated with opportunistic pathogens, toxicants and aesthetic water quality relative to existing plumbing standards.

[3] In this context, toxicants are chemical substances that can lead to adverse health consequences upon ingestion, e.g. plumbing materials that rise to elevated concentrations above guideline values.
[4] In this context, aesthetic water quality refers to perceptible aspects of water, e.g. colour, odour or taste.

The potentially increased risks associated with toxicants and aesthetic water quality presented by the FPAA101D Specification are sufficiently low and insignificant that further study and analysis is not warranted and no modification to the FPAA101D Specification needs to be considered.

The potentially increased risks associated with opportunistic pathogens were considered potentially significant enough to warrant further review of the FPAA101D Specification. These risks were considered further.

3.6 Further consideration of risks associated with opportunistic pathogens

It can be assumed that opportunistic pathogens will persist within the deadlegs feeding sprinklers. Exposure to persons from those pathogens could occur through three principal mechanisms:

- Backflow of water from the sprinkler plumbing to potable plumbing system.
- Cross-connection between the sprinkler plumbing and potable plumbing system.
- Aerosols from toilet flushing with water fed via the toilet flushing feed water.

3.6.1 The standard of backflow prevention required

On the basis of the backflow risk being lower than that accepted from existing deadlegs, (both due to the presence of some existing deadlegs being longer than 3 m and their lacking backflow protection), the recommendation in the FPAA101D Specification, that deadlegs feeding sprinklers limited to a 3 m maximum lineal length be protected from the potable network by both a toilet plumbing feed line and a non-testable dual check valve backflow device, is considered sufficient risk mitigation. Conventional fire sprinkler systems require a testable backflow prevention device but such systems would often carry a greater volume of deadleg water than the proposed FPAA101D Specification and would lack protections such as limitations on lineal length and the regularly turned over toilet plumbing feed line. Existing deadlegs in conventional plumbing systems carry no special protections.

3.6.2 Cross-connection to the sprinkler line

On the basis of the cross-connection risk being similar to that accepted from existing deadlegs, and lower than the risk associated with cross-connections to existing deadlegs on conventional fire sprinkler systems that could be much longer than 3 m, no additional modifications to the FPAA101D Specification are considered necessary. However, as recommended by Queensland Health, some further emphasis on plumbing inspections and signage is warranted for properties installing combined sprinkler systems under the FPAA101D Specification. It is understood that the FPAA101D Specification requires a full system inspection at commissioning. In addition, it is understood that on every floor the FPAA101D sprinkler isolation valve will have a sign to identify the valve and state that the sprinkler system is connected to the toilets on the floor. It would be necessary to isolate this valve before tapping into the FPAA101D system, and tappings should be undertaken by competent licenced individuals. As a benchmark, this is consistent with the observation that plumbing regulators often require higher priority and higher frequency inspections and enhanced signage for dual reticulation plumbing systems that carry non-potable, e.g. recycled, water.

3.6.3 Toilet flushing

Additional risks from exposure to toilet flushing water fed via the sprinkler plumbing lines were considered to be very low. Toilets are widely understood to contain potentially contaminated water and toilets are, by design, not sources of small size-class aerosols. As a result, toilets are a very low likelihood source of opportunistic respiratory infections. Therefore, no special controls or requirements are considered necessary in the FPAA101D Specification.

3.7 Summary of principal recommendations

The principal consideration in agreeing the fine details of the FPAA101D Specification should be whether the potentially incrementally increased risk associated with opportunistic pathogens relative to existing plumbing standards is acceptable. Whilst other risks are noted, the risks from opportunistic pathogens are the most significant and can be considered to be the limiting factor for decision-makers. If controls within the FPAA101D Specification are sufficient to adequately mitigate these limiting risks from opportunistic pathogens then those controls should more than adequately mitigate other risks.

Based on the risk assessment presented here, the controls proposed within the FPAA101D Specification would reduce the risks posed by opportunistic pathogens arising from the fire sprinkler system deadlegs to a level that is in addition to, but lower than, the existing risks posed by other deadlegs within buildings. The reason for this conclusion is that existing deadlegs lack the three key controls within the proposed FPAA101D Specification, being:

i) the hydraulic buffer from the regularly turned over water feeding the toilet;
ii) the non-testable dual check valve backflow device; and
iii) the limitation on deadleg pipe lengths.

Therefore, were a building to have plumbing of a nature, and water of a quality and temperature, that it would support hazardous levels of opportunistic pathogens arising, the FPAA101D Specification would present a risk from fire sprinkler deadlegs that was in addition to, but in and of itself lower than, that posed by other deadlegs within the same building.

Given that the fire sprinkler system has a self-evident benefit (Duranceau et al, 1999), whereas the other deadlegs do not, the proposed FPAA101D Specification presents an acceptable practicable solution since it encourages the installation of fire sprinklers where they might otherwise be absent without presenting more than at worst a marginal, incremental increase in risk from opportunistic pathogens.

4 Introduction

4.1 Purpose

The purpose of this review was to provide an independent, evidence-based and referenced report that assesses the proposed new residential sprinkler design as set out in the Fire Protection Association (FPA) Australia's Technical Specifications "FPAA101D Automatic Fire Sprinkler System Design and Installation – Domestic Water Supply" (draft at the time of writing). The review was undertaken by an independent drinking water quality specialist experienced in assessing risks arising in buildings from plumbing systems with more than one plumbing system (e.g. plumbing for recycled, irrigation, process, flushing and deadleg waters).

4.2 Context

The FPAA101D Specification was a draft at the time of writing with the most recent draft, as seen when completing this review, updated and dated to 21st August 2018. The FPAA101D Specification was developed for the FPA Australia, FRNSW and AFAC Proposal for Change (PFC) to the 2019 National Construction Code (NCC), which seeks to mandate sprinklers in Class 2 and 3 Sole Occupancy Units and common areas in residential accommodation in buildings less than 25 m metres in height. The proposed change will provide for "Combination Domestic Fire Sprinkler Systems" for such buildings to have their sprinklers directly connected to the domestic water supply plumbing rather than being fed by a separate firefighting plumbing system. For such Combination Domestic Fire Sprinkler Systems, the PFC proponents consider that it will not be necessary to install backflow prevention devices on the water supply plumbing directly feeding the sprinklers. The sprinklers will be fed from plumbing supply lines that feed other parts of the property and will often be very short and, as such, the FPAA101D Specification will require non-testable dual check valve backflow prevention rather than testable backflow prevention devices on the feeds to the sprinkler plumbing for each individual sprinkler feed line.

4.3 Scope

The document reports on health and aesthetic risks to persons residing in buildings that have fire suppression systems meeting the proposed FPAA101D Specification.

4.4 Approach

The physical system under consideration was first described in summary form based on what is documented in the FPAA101D Specification. Risks were then assessed for that system, as described. The risk assessment focused on what is different about a plumbing system in a building that meets the proposed FPAA101D Specification as distinct from other more conventional plumbing systems. Risks inherent in the existing, more conventional systems are not assessed in this document since they are considered to be existing, accepted risks. However, direct comparisons are made between risks associated with the proposed FPAA101D Specification and those existing within buildings that meet existing plumbing standards or are known to typically exist within current buildings. This comparison with existing systems is important as it provides a basis for defining a level of acceptable, or at least currently accepted, risk.

5 System description

The system considered in this risk assessment is described in detail in the FPAA101D Specification (FPA Australia, 2018). A concise summary is illustrated as a schematic plumbing diagram (Figure 5-1) and process flow diagram (Figure 5-2). Both diagrams are illustrative with actual configurations being building-specific. The purpose of the diagrams is to conceptually illustrate the principal water flows and process steps. For the purposes of the risk assessment the process flow diagram is used as the principal point of reference. Most of the process is consistent with a conventional drinking water supply plumbing system. Departures from such conventions are:

- A dedicated dual check valve non-testable backflow device and plumbing line supplying the toilet facility.
- A set of dedicated deadleg plumbing lines, meeting the potable water plumbing 'WaterMark' standards, ending with wet sprinklers connected to the plumbing line supplying the toilet.

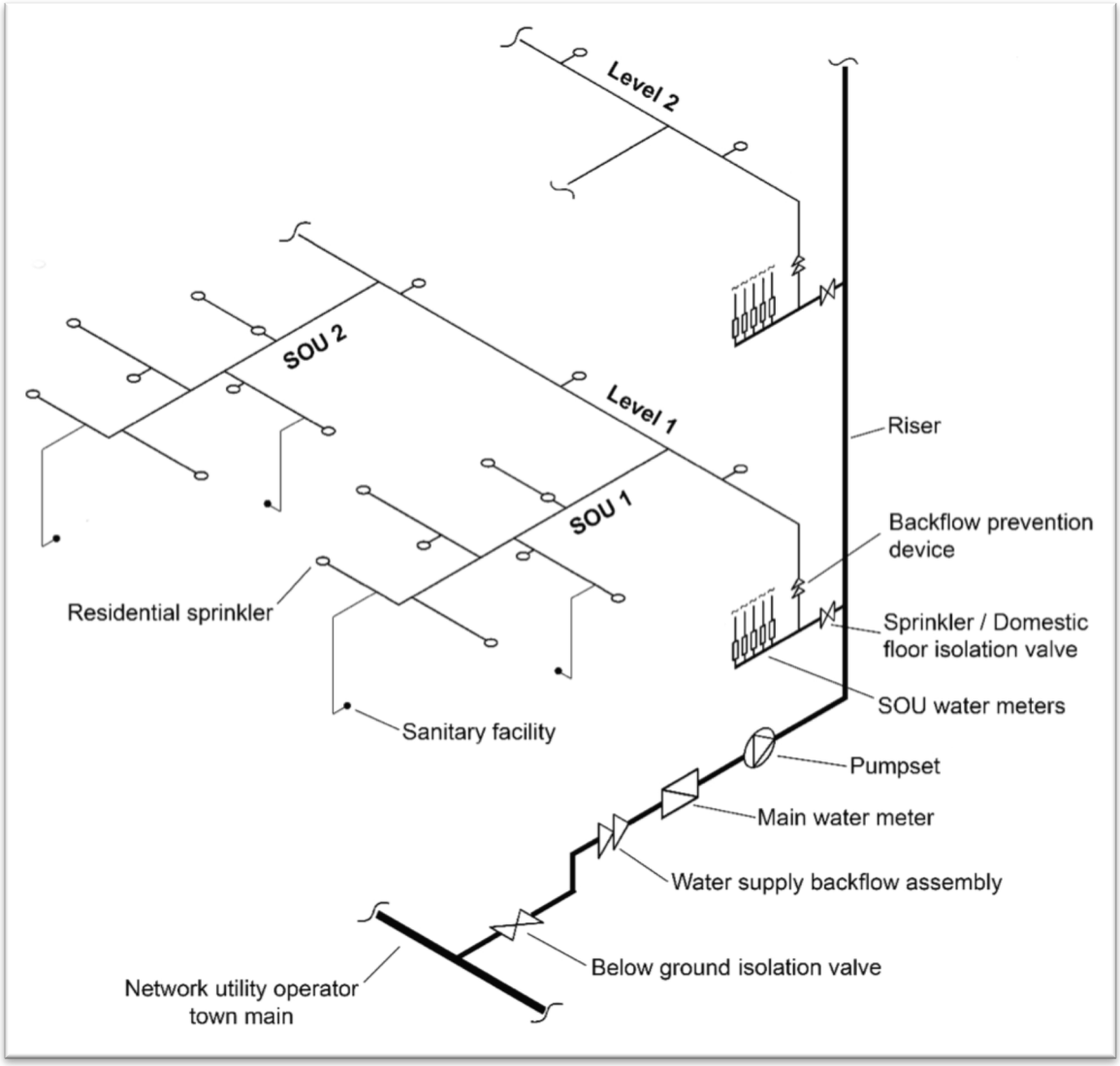

Figure 5-1. Illustrative schematic plumbing system diagram of the proposed FPAA101D Specification sprinkler system (FPA Australia, 2018).

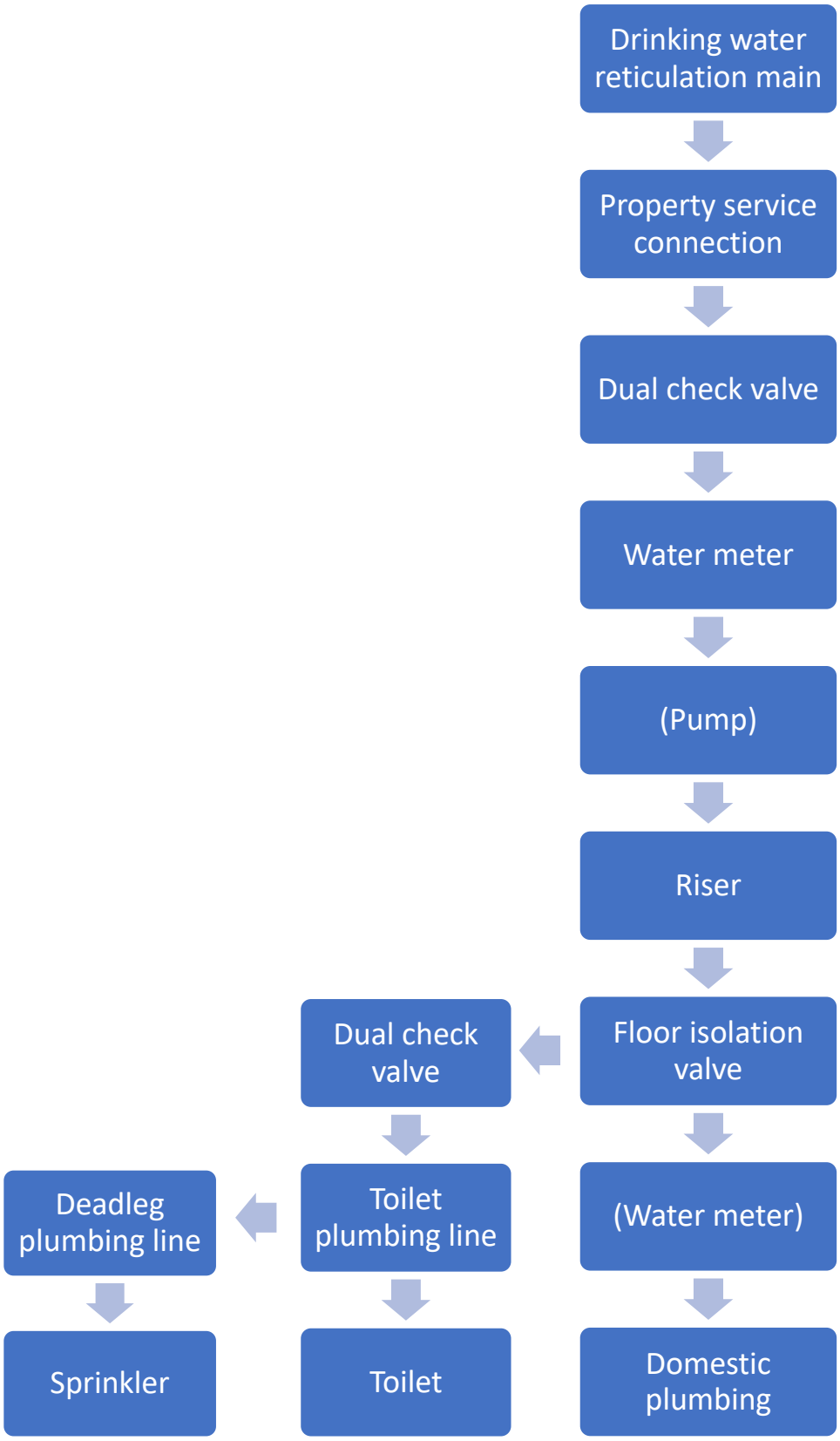

Figure 5-2. Example process flow diagram for a FPAA101D Specification sprinkler system.

6 Risk assessment

6.1 Risk identification

Potential risks that have been identified are described and summarised in Table 4, appended to this report. The risks included were identified largely based upon feedback following expert technical review by stakeholders to the FPA Australia Specification FPAA101D that form the PCC. The stakeholders identifying specific risks noted alongside the summary of risks, below. This report has taken those risks, as identified, and presented them in a structured risk assessment format. Note that the assessment can be modified in response to feedback and includes some qualitative risk assessment rankings that are based on professional judgement.

6.2 Risk assessment methodology

For the purposes of presentation, the risk assessment grouped and ordered risks according to process steps identified within the process flow diagram (Figure 5-1), with risks being assessed for a number of process steps.

The risk assessment focused on what was different about the FPAA101D Specification as distinct from other more conventional plumbing systems. Risks inherent in the existing, more conventional plumbing systems are not assessed in this document since they are considered to be existing, accepted risks.

For each risk, potential contaminants ('hazards') that might be hazardous to human health or aesthetic water quality, and events by which the contaminants could be introduced and/or exacerbated ('hazardous events'), were noted.

Risks were rated as if there were no specific controls given in the FPAA101D Specification (as 'maximum' risks) and then again with consideration being given to the specific controls given in the FPAA101D Specification (as 'residual' risks).

6.3 Risk rating criteria

Risks were rated using the Australian Drinking Water Guidelines (ADWG, 2011) example risk rating criteria, (which is broadly consistent with the approach to risk assessment set out in *AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines*).

For convenience, the ADWG risk rating criteria are reproduced here in Table 1 (likelihood), Table 2 (consequence), and Table 3 (overall rating).

In addition, a record was retained of the basis of the risk rating and a comment was made on the uncertainty, or level of confidence, in that rating. The rated risks are summarised in Table 4, appended to this report.

6.4 Results of the risk assessment

The results of the risk assessment are given in an attached summary table (Table 4) with the live, original file being retained as an Excel workbook for ease of future updating.

Table 1. Risk likelihood rating criteria (image extracted from the ADWG, 2011).

Level	Descriptor	Example description
A	Almost certain	Is expected to occur in most circumstances
B	Likely	Will probably occur in most circumstances
C	Possible	Might occur or should occur at some time
D	Unlikely	Could occur at some time
E	Rare	May occur only in exceptional circumstances

Table 2. Risk consequence rating criteria (image extracted from the ADWG, 2011).

Level	Descriptor	Example description
1	Insignificant	Insignificant impact, little disruption to normal operation, low increase in normal operation costs
2	Minor	Minor impact for small population, some manageable operation disruption, some increase in operating costs
3	Moderate	Minor impact for large population, significant modification to normal operation but manageable, operation costs increased, increased monitoring
4	Major	Major impact for small population, systems significantly compromised and abnormal operation if at all, high level of monitoring required
5	Catastrophic	Major impact for large population, complete failure of systems

Table 3. Risk rating criteria (image extracted from the ADWG, 2011).

Likelihood	Consequences				
	1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic
A (almost certain)	Moderate	High	Very high	Very high	Very high
B (likely)	Moderate	High	High	Very high	Very high
C (possible)	Low	Moderate	High	Very high	Very high
D (unlikely)	Low	Low	Moderate	High	Very high
E (rare)	Low	Low	Moderate	High	High

6.5 Summary of risk assessment findings

6.5.1 Identified risk pathways

A number of risk factors were identified that made a building plumbed in accordance with the FPAA101D Specification somewhat different to one more conventionally plumbed. Water supply distribution and plumbing systems are increasingly being identified as locations in which water supply contamination arises which can in turn result in waterborne disease outbreaks (Craun and Calderon, 2001). Based on these historical reviews of waterborne disease outbreaks, the major credible and established risk pathways of relevance to the FPAA101D Specification include the following:

- Water hammer, pressure transients and changes of pressure, including loss of pressure, could lead to the physical hydraulic drawing of water from deadlegs both back into the potable water supply system and forward into the toilet flushing water.
- Diffusion could lead to the movement of contaminants from deadlegs both back into the potable water supply system and forward into the toilet flushing water.

- Cross-connections, mis-connections and tap-ins that connect plumbing lines not intended to carry potable water to the potable water plumbing lines could transfer contaminants into the potable water.
- In all of the three above examples, there would need to be an exposure pathway for adverse consequences to arise. In relation to failure modes involving the transfer of contaminants into potable water, exposure pathways could include aerosol inhalation, ingestion and skin, nose or eye contact. In relation to failure modes involving transfer of contaminants into the toilet flushing water, important exposure pathways are most likely limited to aerosol inhalation.

6.5.2 Specific controls of significance

A number of specific controls given in the FPAA101D Specification were of significance in that they significantly reduced maximum risks and thereby reduced the rating given to the residual risks. These significant controls included the following:

- "2.5.3.2.1 Sprinkler pipework deadlegs/stagnant water. The sprinkler system pipework shall be designed and installed so that no part of any pipework containing stagnant water is more than 3 m in lineal length."
    - This control significantly limits both the potential surface area and volume that could give rise to risks associated with corrosion products and biofilm formation and to stagnant water and leaching within those deadlegs.
- "2.5.3.2.3 Backflow prevention. A backflow prevention device in accordance with Clause 5.3.2 shall be installed on the sprinkler pipework..."
    - This control reduces the likelihood of water flowing from deadlegs back into the main potable water system using non-testable dual check valve devices.
- "2.5.3.2.4 Connection to toilets. All toilets shall be connected and supplied directly from the sprinkler system..."
    - This control provides a means to keep water turning over in the main feeder line to the deadlegs as well as providing a hydraulic barrier with a volume of regularly turnover over water sitting as a buffer between the deadlegs and the main potable system. The hydraulic buffer won't prevent backflow in the event of total pressure loss but will help mitigate the effects of diffusion and minor hydraulic transfers due to water hammer and pressure transients.
- "2.5.3.3 Connection to other systems. Other than detailed in this Specification, no part of the sprinkler system shall be connected to any other service including drencher systems, wall wetting systems, hose reels or the like."
    - This control helps to minimise the extent to which the main feeder line to the deadlegs and the deadlegs themselves might be connected to other components of the plumbing system which might in turn lead to elevated exposure to water influenced by stagnant water from those deadlegs.

6.5.3 Summary of risks relating to enteric pathogens

Enteric (gastrointestinal) pathogens are microorganisms that infect the gastrointestinal tract and that can be transmitted by potable water include bacteria (e.g. *Salmonella* spp. and *Campylobacter* spp.), parasites (e.g. *Cryptosporidium* spp.) and viruses (e.g.

norovirus) (ADWG). They typically cause diarrhoea and vomiting and can cause more complex symptoms, and sometimes death. In general, in relation to waterborne disease, enteric pathogens are the most hazardous contaminant that has historically caused the most harm to health from contaminated drinking water. The primary purpose of providing safe water is to prevent transmission of enteric pathogens. Therefore, risks associated with enteric pathogens were considered first.

Enteric pathogens are typically only present in water if that water has become contaminated with faecal matter or putrescing food waste. They are no more likely to be present in deadleg fire sprinkler lines than in any other plumbing since they do not typically persist or grow in potable water, but rather they gradually die off over time.

It was concluded that enteric pathogens are primarily derived from fresh faecal matter and are not specifically of concern in deadlegs or pipework. The relatively low nutrients found in potable water do not typically support the proliferation of enteric pathogens even in the absence of a disinfectant residual, e.g. in deadlegs.

Significant concentrations of enteric pathogens capable of resulting in significant consequences are not posed by the proposed FPAA101D Specification, even without any dedicated controls, resulting in both a low maximum and low residual risk. Therefore, risks posed by enteric pathogens were not considered further.

6.5.4 Summary of risks relating to opportunistic pathogens

Opportunistic pathogens are microorganisms that are naturally present in water and that aren't ordinarily, (as part of their ordinary ecological niche or lifecycle), pathogenic to humans. However, these microorganisms can potentially cause infections in humans 'opportunistically' if the opportunity to infect a person arises. Potable water can provide a means to transmit such pathogens if exposure pathways arise (Bentham *et al*., 2007). Infections can occur via skin contact, eyes, ingestion, inhalation and nasal contact.

The higher the concentration of such microorganisms in water, the higher the risk. The relevance to the FPAA101D Specification is that such opportunistic pathogens can proliferate to levels of concern in stagnant water. The risks rise where the pathogens can form as part of biofilms (e.g. on pipe surfaces), in water lacking a disinfectant residual (e.g. in deadlegs where water is not turned over to bring in fresh, effective disinfectant), and in warm water (e.g. in the 20 to 50˚C temperature range, and particularly in water that is continually above 25˚C, or seasonally above 30˚C for months at a time).

Of most significance within the Australian context this group of microorganisms includes bacteria, such as *Legionella* spp. (that infects the respiratory system) and amoebae, such as *Naegleria* spp. (that infects the brain via the nose) and *Acanthamoeba* spp. (that infects the eyes).

The risk assessment found that without adding any special controls, adding wet sprinkler systems to the potable building plumbing network would present a risk of opportunistic pathogens backflowing and diffusing into the potable plumbing system, being transferred forward into the toilet flushing water and being fed into the potable water system via cross-connections. Connecting deadleg sprinkler supply lines provides the potential for proliferation of opportunistic pathogens within those deadlegs resulting in a potentially very high risk if uncontrolled.

To respond to that risk, three controls were noted in the FPAA101D Specification that reduced the risk relative to what it would have been with no such controls. These controls are summarised in section 6.5.1, above. Briefly, the proposed controls mean that the length of deadleg pipework is minimised, the risk of backflow is reduced, and the water running to the toilet will provide a hydraulic buffer of water that is turned over between the deadleg pipework and the potable plumbing system. Only the first of these three controls was relevant to the toilet flushing water but exposures to toilet flushing water were considered to be much more limited in terms of both their pathway and potential extent (limited to low likelihood of sporadic aerosol inhalation). It is noted that conventional fire sprinkler systems with a second plumbing system have only one protection against this risk, being the testable backflow prevention device.

The proposed controls will reduce, but not eliminate, the risk of opportunistic pathogens diffusing or being drawn back into, or cross-connected into, the potable plumbing system, or of being inhaled following toilet flushing. However, it was noted that, particularly for risks related to backflow or cross-connection, the risk is further mitigated by the likelihood that stagnant water would often be associated with elevated colour, particulates, taste or odour (discussed in section 6.5.6) and would, therefore, typically be discernible.

It should be noted that the risk of opportunistic pathogens being present at concentrations of concern is heavily temperature-dependent, and that risks to health are related to the age of exposed persons. With increased global average temperatures, and increased life expectancy and hence more aged persons, the risks posed by opportunistic pathogens is increasing globally. Much of Australia is in climatic zones where water temperatures routinely reside above the 25˚C range at which opportunistic pathogen growth is most problematic. For instance, ambient water temperatures can routinely exceed 30˚C in much of northern Australia and indoor shade air temperatures, in the absence of air conditioning, can often range between the mid-twenties to high thirties of ˚C throughout much of the year. The implications are that all plumbing in Australia will often be, and will increasingly be, in the temperature range that will support the growth of opportunistic pathogens to levels of concern in the absence of disinfectant residuals, e.g. in deadlegs. On the other hand, the scale of buildings that are intended to house the fire sprinkler systems described in the FPAA101D Specification are likely to be relatively-well protected from extremes of heat and are likely to be insulated and cooled, unlike small, isolated dwellings.

It is important to note that the incidence of opportunistic pathogen infections attributed to drinking water supplies and plumbing systems, (as distinct from established high risk sources, such as cooling towers), has been increasing in recent decades. Some of the most striking evidence of this comes from the US Centres for Disease Control (CDC) who undertake systematic long-term reporting on waterborne disease for the US. No equivalent reporting is available for Australia, which is why US data is presented in this report. Recent US reports show, for instance, that during the most recent reporting year (2013–2014), of the 42 drinking water–associated outbreaks, the opportunistic pathogen *Legionella* was associated with 57% of the outbreaks and all of the reported 13 deaths (Benedict *et al*., 2017). The evidence shows this to be in line with trends and not an isolated event, with figures showing that in the past decade opportunistic pathogens have

overtaken other agents as the major cause of waterborne disease outbreaks associated with drinking water in the US (Figure 6-1).

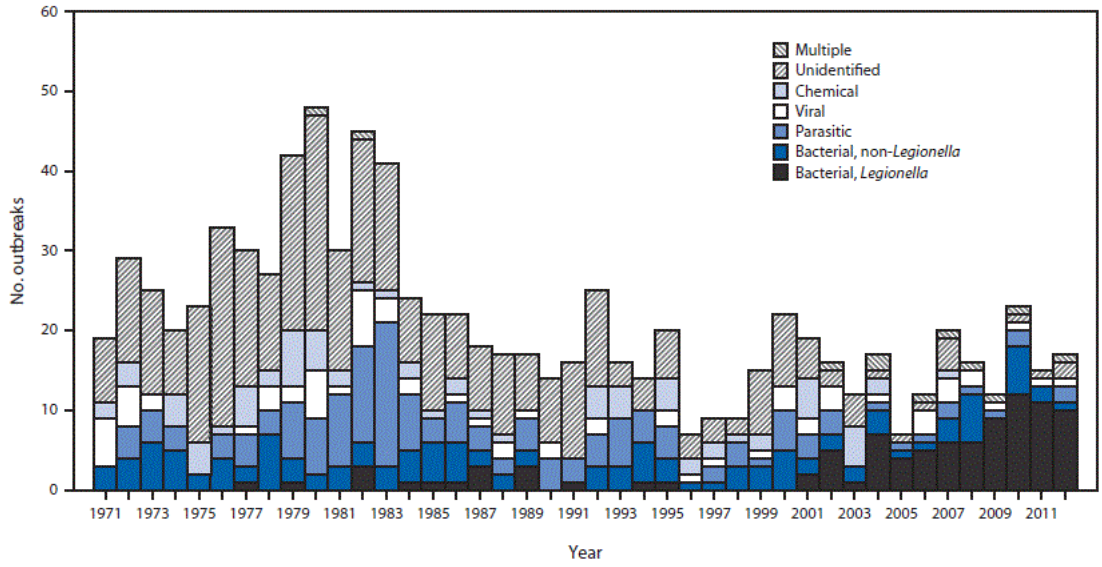

Figure 6-1. Aetiology of 885 drinking water–associated outbreaks, by year — United States, 1971–2012. US Centres for Disease Control (Beer et al, 2015).

In summary, for opportunistic pathogens, the risk assessment rated the residual risk as rare in likelihood but captured the fact that, being fatal, opportunistic pathogens can present major localised consequences. This risk needs careful evaluation as is discussed below to decide whether the controls are adequate such that the risk is acceptable.

It is noted that short deadlegs already exist within existing plumbing systems, and many don't have any backflow prevention or length limitation, as proposed with the FPAA101D Specification. It is probable that, on balance the risk is not significantly higher than the risk associated with conventional plumbing systems. The risk associated with conventional plumbing systems is currently accepted and plumbing systems are not operated as zero or near zero risk systems. Nonetheless, given the high consequence rating for this risk, the it requires special deliberation in evaluating the FPAA101D Specification. These risks were considered in more depth in section 7.1.3 of this report.

6.5.5 Summary of risks relating to toxigenic chemicals

Toxigenic chemical hazards can arise from plumbing fittings, (e.g. copper, lead, cadmium, chromium or plastics), leached and/or corroded from plumbing deadlegs. Over time the concentrations of chemical substances that may leach from pipes, or form in corrosion products and then leach into the water, could readily reach levels that exceed ADWG guideline values in deadlegs. More likely than not one or more chemicals will exceed ADWG guideline values in stagnant water residing in plumbing pipes and fittings that comply with the WaterMark certification scheme and *AS/NZS 4020:2005. Australian/New Zealand Standard. Testing of products for use in contact with drinking water*. These standards and compliance systems reduce the risk of toxigenic chemicals being present in plumbing but only provide a high level of assurance of such protection for pipes and fittings that are adequately turned over. That is, WaterMark-compliant plumbing will be less subject to corrosion and leaching than other plumbing, but deadlegs can still permit

contamination to arise to levels above health-related guideline values, albeit to lower levels than would arise from plumbing that was not WaterMark compliant.

It was considered that the proposed FPAA101D Specification will provide the potential for chemicals to reach concentrations of concern within deadlegs resulting in a potentially high risk.

The controls proposed within the FPAA101D Specification (summarised in section 6.5.1) mean that the length of deadleg pipework is minimsed, the risk of backflow is reduced, and the water running to the toilet will provide a hydraulic buffer of water that is turned over between the deadleg pipework and the potable plumbing system. The controls will reduce, but not eliminate, the risk of chemicals reaching levels that exceed guideline values being ingested. However, with such short deadlegs, very limited exposures would occur, for isolated events, and typically with water that is evidently contaminated through colour, taste, particulates, or odour, and unlikely to be consumed in large quantities, and not foreseeably consumed for prolonged periods. The latter point is important since it renders the risks relating to toxigenic chemicals self-limiting. For instance, elevated metals in stagnant water would typically be evident as both colour or taste.

In practice, whilst short term exceedances of chemical guideline values might arise, exposure periods would be too short, exposures too infrequent and adverse aesthetic properties too self-limiting to present significant health consequences. It was concluded that the risk is acceptable and is similar to, and at worst only incrementally and marginally higher than, the risk associated with conventional plumbing systems. Therefore, risks posed by toxicants were not considered further.

6.5.6 Summary of risks relating to aesthetics

Aesthetic hazards in water can reach levels that cause perceptible taste, odour, particulates and colour. Over time the concentrations of substances that may leach, form in biofilms, or arise in corrosion products could reach levels that are detectable as colour, particles, tastes or odours. As noted in section 6.5.5, the WaterMark certification scheme and *AS/NZS 4020:2005. Australian/New Zealand Standard. Testing of products for use in contact with drinking water* only assure full protection for pipes and fittings that are adequately turned over. That is, WaterMark-compliant plumbing will be less subject to corrosion and leaching than other plumbing, but deadlegs can still permit contamination to arise to levels above aesthetic guideline values, albeit to lower levels than would arise from plumbing that was not WaterMark compliant

It was considered that the proposed FPAA101D Specification will provide the potential for substances to reach discernible concentrations within deadlegs resulting in a potentially moderate risk.

The controls proposed within the FPAA101D Specification (summarised in section 6.5.1) mean that the length of deadleg pipework is minimsed, the risk of backflow is reduced, and the water running to the toilet will provide a hydraulic buffer of water that is turned over between the deadleg pipework and the potable plumbing system. The controls will reduce, but not eliminate, the risk of substances reaching levels that are discernible. However, with such short deadlegs, very limited exposures would occur, for isolated events, and not foreseeably for prolonged periods.

In practice, whilst short term exceedances of aesthetic guideline values might arise, exposure periods would be too short, and instances too infrequent, to present significant consequences. Furthermore, the risk is acceptable and is similar to, and at worst only incrementally and marginally higher than, the risk associated with conventional plumbing systems. Therefore, risks posed by aesthetic hazards were not considered further.

7 Discussion of findings of the risk assessment

7.1 Priorities and limiting hazards

There were low, moderate and high consequence hazards identified in the risk assessment. However, in practice, the controls required to reduce the risks from higher consequence hazards to an acceptably low level are likely to more than adequately reduce the risks posed by less consequential hazards. Therefore, the focus of an assessment of the FPA101D Specification should be on ensuring that the controls aimed at managing the higher consequence hazards are adequate. The principle is that if higher, limiting, risks are adequately controlled, then the lower risks will, by default, be adequately mitigated, provided the mitigation measures identified are relevant to both groups of risks. Since the recommended controls proposed under the FPAA101D Specification (as summarised in section 6.5.1) are largely physical and hydraulic in nature, they will mitigate the various hazards in similar ways, which supports relying upon management of the limiting and most significant hazard and risk as being justifiably the focus of this assessment.

7.1.1 Low consequence hazards

The low consequence hazards include materials that may cause aesthetic, but not health-related, consequences. These may present as colour, taste, particulates or odour. Such risks could arguably be accepted on the basis of their low 'nuisance' rather than moderate or high 'health' consequence. In addition, as noted above, hydraulic mitigation of higher, limiting, risks should serve to mitigate these lower risks. Therefore, risks posed by aesthetic hazards were not considered further. Similarly, enteric pathogens are not discussed further since they were considered to present no additional risk from adopting the FPAA101D Specification.

7.1.2 Moderate consequence hazards

Moderate consequence hazards include chemical toxicants that will potentially be present above guideline values, but only for brief periods and infrequently, and most likely in association with colour, particulates, taste or odour, limiting the likelihood of their ingestion. Therefore, such risks could arguably be accepted on the basis of their moderate consequence. In addition, as noted above, hydraulic mitigation of higher, limiting, risks should serve to mitigate these more moderate risks. Therefore, risks posed by toxicant hazards were not considered further.

7.1.3 High consequence, limiting hazards

The only high consequence hazard presented relates to opportunistic pathogens. The key to ensuring that the risks associated with the FPAA101D Specification are acceptable is to reduce the risk posed by opportunistic pathogens to an acceptably low likelihood. The controls required to reduce this opportunistic pathogen risk to an acceptably low likelihood are likely to more than adequately reduce the risk posed by the less consequential hazards, noted above.

7.2 Most significant and limiting hazardous events

The risks posed by backflow were identified as the most significant of the failures modes and hazardous events assessed. Therefore, a key question relating to the acceptability of the proposed FPAA101D Specification relates to the acceptability of the backflow risk. From a design, installation, inspection and maintenance perspective, the focus in finalising the FPAA101D Specification should be on specifying the controls required to adequately mitigate that backflow risk.

7.2.1 Currently accepted risks

A key finding when considering the backflow risk was that there are routinely many low turnover and zero turnover deadleg pipes and fittings in existing plumbing systems. Therefore, the FPAA101D Specification presents risks similar in nature and magnitude to those associated with conventional plumbing systems. Potentially the FPAA101D Specification presents lower risks than conventional plumbing systems. The reason for this difference is that conventional plumbing systems often include low turnover and deadleg pipes and fittings without the backflow prevention or length limitation controls given in the proposed FPAA101D Specification (as summarised in section 6.5.1). Examples of such existing pipes and fittings may include:

- Entire building plumbing systems in infrequently used properties, e.g. short-term lease properties or holiday units that may go unused for some weeks or even months between uses.
- Entire building plumbing systems in sites that close down for prolonged periods, e.g. seasonal holiday buildings, educational establishments, commercial or industrial facilities, that may not be in use for many weeks at a time.
- Infrequently used plumbing lines, taps and fittings supplying points outside buildings, such as hose fittings to taps that are seldom used, or seasonally used taps and fittings, such as outdoor showers, irrigation lines or pool filling points. These may be connected to long hose reels and irrigation lines of considerable length.
- Infrequently used plumbing lines, taps and fittings inside buildings, such as rooms with ensuites that are not in use, abandoned showers or baths that are leaking and not in use, or taps supplying appliances that are no longer, or seldom, used.
- Infrequently plumbing lines and safety fittings, such as eye wash stations or emergency showers.
- Abandoned and plugged pipe lengths arising when properties are modified and pipes are left in place and remain plumbed into the water supply plumbing, forming a deadleg with no turnover.

The use of a non-testable dual check valve, as proposed in the FPAA101D Specification, reduces the risk of contamination flowing back into the potable network to less than the risk associated with existing deadlegs, such as those listed above. However, as to whether the risk is low enough to be acceptable comes down to professional judgement in the absence of objective evidence from field experience. Since the FPAA101D Specification is new, there is not a longstanding field site to use for direct assessment.

Within existing plumbing arrangements, larger fire systems must be protected with a testable device. Therefore, if a special case is made for the smaller fire systems to only be

protected by a non-testable dual check valve, then some criteria need to be placed around that in order to justify foregoing the testable device. Those criteria can include:

- Limiting the size and scale of the building (25 m in height is proposed in the case of the FPAA101D Specification);
- setting a maximum length on deadlegs (3 m is proposed in the case of the FPAA101D Specification); and
- the need for the line feeding the deadlegs that lead to the sprinklers to be connected to a system that does flow (e.g. a toilet is proposed in the case of the FPAA101D Specification).

The focus of this assessment comes down to deciding whether these additional controls are adequate and, if not, what controls would be sufficient. Assessment of the adequacy of those controls can be focused on consideration of the most significant, or limiting, risks, in this case, the risks posed by opportunistic pathogens, as discussed in the following sub-section.

7.3 Relative risk assessment relating to opportunistic pathogens

As noted above (section 7.2.1), currently accepted risks included some low, or even no, turnover taps and fittings within buildings.

Installing additional no turnover fittings, in this case fire sprinkler feed deadlegs, within buildings, as recommended under the FPAA101D Specification, unquestionably increases the risks associated with opportunistic pathogens. The risk is increased by virtue of the increased surface area presented and increased length of pipe installed that is intended to be subject to no significant turnover relative to the normal situation.

However, from a relative risk perspective, the FPAA101D Specification as proposed presents an *incremental increase* in risk rather than a *step change* in risk or a *new* risk. That is, the extent of low and no turnover plumbing pipes and fittings will increase above current levels under the FPAA101D Specification, but no completely new and currently non-existent category of risk is introduced.

Furthermore, as noted in section 6.5.1, additional controls are proposed in the FPAA101D Specification for the wet sprinkler systems: a dual check valve non-testable backflow device; turnover of the plumbing line feeding the deadlegs using the toilet flushing supply line; and limiting deadlegs to at most 3 m linear length. These controls significantly reduce the extent of the incremental increase in risk from backflow. The key question to be addressed is: are those controls sufficient, and is the incremental increase in risk acceptable? This question is considered in the following discussion.

7.4 Professional assessment of the risk from opportunistic pathogens

A quantitative assessment of risk is discussed but was not undertaken for the reasons explained below (7.5). Therefore, the exercise of professional judgement, based on the objective evidence, has been used to inform a professional opinion on the acceptability and adequacy of the controls proposed under the FPAA101D Specification. In order to support such judgement, existing evidence was assembled and reviewed.

7.4.1 Length of deadlegs

One important control identified in the FPAA101D Specification is to draw a line with respect to how long deadlegs can be. Whilst drawing such lines based on evidence and theoretical risk can be difficult, and there may be varying views on where that line should be drawn, there is likely to be consensus that some working upper limit on the length of deadlegs should be set.

Fortunately, the proposed FPAA101D Specification has been able to draw directly from evidence from research carried out in NZ (Soja, 2006) in setting a limit on the length of deadlegs. In that respect, the FPAA101D Specification can be considered to be evidence-based. That research studied microbial and chemical water quality in domestic fire sprinkler systems over one year. The report concluded:

> "It was found that the microbial quality would not be hazardous to health where range pipe dead legs were up to 4.5 metres long for a water supply of equal or better quality to that used in this research. From this it is recommended that dead legs up to 3 metres could be used in Combination Domestic Fire Sprinkler Systems."

It is noted that one of the controls recommended in the FPAA101D Specification is to limit linear lengths of deadlegs to 3 m (section 6.5.1). This control appears to be important and drawing the line based on the Soja (2006) study seems appropriate given that more recent evidence has not been identified that suggests that this recommendation should be modified. Therefore, it is considered that the recommendation in the FPAA101D Specification that deadlegs be limited in length to 3 m can be accepted.

7.4.2 The standard of backflow prevention required

The Backflow Prevention Association of Australia (BPAA), Queensland Health and WA Building and Energy, Plumbing Technical Reference Group have all strongly questioned the idea that sprinkler systems connected to the potable water supply under the FPAA101D Specification can avoid the need to protect those systems using testable backflow prevention devices. Therefore, a key decision in finalising the FPAA101D Specification relates to whether the backflow risks arising under the FPAA101D Specification arrangements are of a magnitude that the backflow protection can just be based on a dual check valve non-testable backflow device as currently proposed (section 6.5.1), or whether an accessible and testable device is required.

A similar question was considered in a study from the US by NFPA (2009). The study concluded that it was not uncommon for residential combination fire sprinkler systems to be supplied without testable backflow prevention devices, including in warm climate southern US states. Problems with backflow from such residential combination fire sprinkler systems were not commonly reported under routine, field conditions in the research, and backflow prevention was not considered necessary in many of the jurisdictions surveyed.

An earlier US study (Duranceau et al, 1999) found that, under simulated conditions using a single check valve, unrestricted deadleg length and no toilet connection flow through, backflow from sprinkler system deadlegs was observed, with a range of hazardous chemicals and microbial indicators of stagnant water being detected. However, the authors concluded that the risks posed by such events were too low to justify retrofitting

backflow prevention to existing residential combination fire sprinkler systems given the relatively low risks implied compared the very high risks associated with fires.

A useful consideration in making a decision on the level of backflow prevention required in the FPAA101D Specification is 'relative risk'. Existing plumbing systems contain deadlegs that are not routinely protected by any backflow prevention system. The FPAA101D Specification has not proposed to use a testable backflow device, such as would be required for a medium hazard connection. But the FPAA101D Specification has proposed to use a non-testable dual check valve backflow device. This position appears to be a pragmatic solution that reduces the risk of backflow associated with the fire sprinkler system to lower than that associated with other deadlegs. In addition, the water supplying the toilet line provides a hydraulic buffer of water that is likely to be regularly turned over such that only quite significant backflow events would draw water into the potable plumbing system if the backflow device failed.

On the basis of the risk being lower than that accepted from existing deadlegs, (both due to the presence of some existing deadlegs being longer than 3 m and their lacking backflow protection), the recommendation in the FPAA101D Specification, that deadlegs feeding sprinklers be protected from the potable network by both a toilet plumbing feed line and a non-testable dual check valve backflow device, is considered sufficient risk mitigation.

7.4.3 Cross-connection to the sprinkler line

Queensland Health have raised concerns about cross-connections. Cross-connections, mis-connections and inadvertent tap-ins could occur and then connect the plumbing lines feeding the toilet and sprinkler plumbing deadlegs to the potable water. The connected taps and fittings could be influenced by the deadlegs supplying the sprinklers. Such connections are likely to occur without any backflow device in place and could affect both the immediate connection in the case of single tap-ins as well as other connections in the case of full cross-connections. During building commissioning, existing full cross-connections would be readily identified when domestic or sprinkler system plumbing were attempted to be isolated and tested, but if such events occurred over time when plumbing works were carried out such connections might be missed.

The relevant hazards and risks associated with cross-connections are largely the same as those associated with backflow with the exception of the fact that cross-connections could be continuous, whereas backflow events are likely to be sporadic.

It is noted that one of the controls recommended in the FPAA101D Specification is to limit linear lengths of deadlegs to 3 m and to minimise connections to other systems (section 6.5.1). Whilst a cross-connection of some sort is reasonably foreseeable, (with cross-connections reported many times per year around Australia in recycled water networks for instance), with such a limited extent for the deadlegs, the risks arising from such cross-connections would be relatively low, and no higher than that associated with the risk of existing deadlegs that are present in plumbing systems. Such cross-connections can already occur between the potable plumbing and conventional fire sprinkler systems, recycled water, irrigation water, roof-harvested rainwater and other non-potable water plumbing systems.

On the basis of the cross-connection risk being similar to that accepted from existing deadlegs, (and lower than the risk associated with cross-connections to existing deadlegs longer than 3 m), no additional modifications to the FPAA101D Specification are considered necessary. However, as recommended by Queensland Health, some further emphasis on plumbing inspections and signage is warranted for properties installing combined sprinkler systems under the FPAA101D Specification. As a benchmark, plumbing regulators often require higher priority and frequency inspections and enhanced signage for dual reticulation plumbing systems.

7.4.4 Toilet flushing

It is possible that occasional splashes or droplets of toilet flushing water could be inhaled leading to exposure to opportunistic pathogens within those droplets. However, it is widely understood in the community that toilets contain hazardous water due to their primary goal of capturing faecal matter, vomit and blood. By design, toilets are designed to capture, and not spray or spread water. The community has good awareness of the need not to ingest or contact toilet water. In addition, toilets are not sources of significant quantities of aerosol contamination and they are in particular not sources of small size-class aerosols. Therefore, whilst traces of opportunistic pathogens might find their way from fire sprinkler feed deadlegs to toilets via the toilet flushing line, the risks from such transfers to health would be minimal due to the absence of a significant exposure pathway.

In summary, exposures to toilet flushing water would be very low due to toilets being widely understood to contain potentially contaminated water. In addition, by design, toilets are not sources of small size-class aerosols meaning that they are not a high likelihood source of opportunistic respiratory infections. Therefore, no special controls or requirements are considered necessary in the FPAA101D Specification.

7.5 Quantitative risk assessment

7.5.1 Toxicological risk assessment

A toxicological risk assessment (TRA) can be used to set quantitative limits on risks associated with chemicals against defined targets. In this case, a TRA was not undertaken to support this assessment. It was concluded from the qualitative risk assessment that risks from chemicals pathogens were not significant given that any exposures to hazardous chemicals arising from plumbing leaching and corrosion would be rare, sporadic, short in duration and typically associated with elevated colour, particulates, taste or odour. No additional assessment was required since the resulting residual risk was considered acceptable.

7.5.2 Quantitative microbial risk assessment

A quantitative microbial risk assessment (QMRA) can be used to set quantitative limits on risks associated with pathogen against defined targets. In this case, a QMRA was not undertaken to support this assessment.

QMRA is often applied to assessing risks from enteric pathogens and would have been completed were enteric pathogens considered potentially of significant risk. However, the qualitative risk assessment concluded that risks from enteric pathogens were not

significant and were no higher than existing risks from conventional plumbing systems. No additional assessment, including a QMRA, was considered required since the resulting residual risk was considered acceptable.

QMRA can be applied to assessing risks from opportunistic pathogens. However, at present, such techniques are of very limited value in assessing risks from opportunistic pathogens (Bentham and Whiley, 2018). The major risks of concern in the review of the FPAA101D Specification related to opportunistic pathogens and not enteric pathogens. Therefore, the above qualitative risk assessment was used as the basis to consider the acceptability of risks and requirements of controls, rather than a QMRA that would be too uncertain to provide a helpful contribution to decision-making.

8 Conclusion

Implementing the FPAA101D Specification does not present new classes or categories of risks from enteric pathogens, opportunistic pathogens, toxicants or aesthetic hazards that are not already present in existing potable plumbing systems. All such plumbing systems have the potential to contain some deadlegs with very low or no turnover that can in turn influence the potable water system via backflow or cross-connection.

Relative to a building with no fire sprinkler system, implementing the FPAA101D Specification adds the potential for some additional deadlegs and, hence, an incrementally increased risk from such hazards. However, the FPAA101D Specification includes a number of controls to reduce those risks for the fire sprinkler systems to lower than the levels associated with other deadlegs, namely:

- limiting deadlegs to maximum 3 m lineal lengths;
- providing backflow prevention via a non-testable dual check valve; and
- providing for a hydraulic barrier with the plumbing line feeding the sprinkler lines being turned over through connection via the toilet.

The presence of such controls means that incremental increases in existing risks from having the FPAA101D Specification fire sprinkler systems in place is small relative to existing risks presented by existing plumbing deadlegs that have no such protection.

Relative to a building with a conventional separate fire sprinkler system, implementing the FPAA101D Specification is likely to be present lower dead water volumes in less deadlegs than those presented by conventional separate fire sprinkler systems. The conventional separate fire sprinkler systems are separated from the potable water system by a testable backflow prevention device whereas the FPAA101D Specification includes non-testable dual check valve protection. However, the FPAA101D Specification includes additional controls not present in conventional separate fire sprinkler systems, namely:

- limiting deadlegs to maximum 3 m lineal lengths;
- providing for a hydraulic barrier with the plumbing line feeding the sprinkler lines being turned over through connection via the toilet; and
- all components being WaterMark compliant and so less prone to corrosion and leaching of toxicants and aesthetically objectionable hazards.

The presence of such controls means that if there is an increase in risk it is very small relative to the existing risk presented by conventional separate fire sprinkler systems that are only protected by a single backflow protection barrier, albeit a testable device.

In summary, whilst there are risks arising from implementing the FPAA101D Specification, those risks are comparable to accepted risks found in potable plumbing systems, including those with no fire sprinkler systems but having some deadlegs, and those with conventional separate fire sprinkler systems. The fire safety risks from having no automatic fire sprinkler systems are well established. Therefore, if the FPAA101D Specification encourages the uptake of fire sprinkler systems where they might otherwise not be implemented, e.g. where installing conventional separate fire sprinkler systems is considered impractical or cost prohibitive, the FPAA101D Specification, with its multiple controls to protect potable water quality, presents an acceptable, practical solution to increase the update of fire sprinkler systems.

9 References

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Table 4. Risk assessment summary table

Process Step (from flow diagram)	Contaminants ('hazards')	How can the hazard be introduced or exacerbated as a result of the proposed FPAA101D standard? ('hazardous events')	Likelihood (A-E)	Severity (1 to 5)	Maximum Risk (no specific controls)	Controls ('preventive measures') that are proposed in FPAA101D	Residual Likelihood (A-E)	Residual Consequence (1 to 5)	Residual Risk (with proposed controls)	Notes on basis of the scoring	Uncertainty	Acceptability of risk	Follow up actions
Deadlegs feeding sprinklers	Enteric pathogens including bacteria (e.g. *Salmonella* spp. and *Campylobacter* spp.), parasites (e.g. *Cryptosporidium* spp.) and viruses (e.g. norovirus).	These pathogens are only present in water contaminated with faecal matter or putrescing food waste. They are no more likely to be present in deadleg fire sprinkler lines than in any other plumbing since they do not typically persist or grow in potable water, but rather they gradually die off over time. If the water **backflows** into the potable system persons may be exposed via ingestion.	E	1	Low		E	1	Low	Enteric pathogens are primarily derived from fresh faecal matter and are not specifically of concern in deadlegs or pipework. The relatively low nutrients found in potable water do not typically support the proliferation of enteric pathogens even in the absence of a disinfectant residual, e.g. in deadlegs. Significant concentrations of enteric pathogens capable of resulting in significant consequences are not presented by the proposed standard, even without any dedicated controls, resulting in a low maximum and residual risk.	High level of confidence. The source, fate and transport of enteric pathogens in water is well understood.	The risk is acceptable and is no higher than the risk associated with conventional plumbing systems that already include low turnover plumbing lines and fittings, often without backflow prevention or length limitations on deadlegs.	None.
Deadlegs feeding sprinklers	Opportunistic pathogens including bacteria such as *Legionella* spp. and amoebae such as *Naegleria* spp. and Acanthamoeba spp.	These pathogens are present naturally in water. They proliferate to levels of concern in stagnant water, particularly where they can form biofilms (e.g. on pipe surfaces), in water lacking a disinfectant residual (e.g. in deadleg pipes) and in warm water (e.g. in the 20 to 50˚C temperature range). If the water **backflows** into the potable system persons may be exposed, e.g. via inhalation, eye, nose or skin contact.	C	4	Very High	2.5.3.2.1 Sprinkler pipework deadlegs/stagnant water. The sprinkler system pipework shall be designed and installed so that no part of any pipework containing stagnant water is more than 3 m in lineal length. 2.5.3.2.3 Backflow prevention. A backflow prevention device in accordance with Clause 5.3.2 shall be installed on the sprinkler pipework... 2.5.3.2.4 Connection to toilets. All toilets shall be connected and supplied directly from the sprinkler system...	E	4	High	The proposed standard will increase the potential for proliferation of opportunistic pathogens by providing increased surface area and deadlegs resulting in a potentially very high risk. The controls proposed mean that the length of deadleg pipework is minimsed, the risk of backflow is reduced, and the water running to the toilet will provide a buffer of water that is turned over between the deadleg pipework and the potable plumbing system. The controls will reduce, but not eliminate, the risk of opportunistic pathogens diffusing or being drawn back into the potable plumbing system. The risk is further mitigated by the likelihood that backflow of stagnant water would be associated with elevated colour, particulates, taste or odour. The resulting residual risk remains rare in likelihood but could have a major localised impact if the controls fail.	Moderate level of confidence. The presence of deadlegs similar to those proposed is not uncommon in existing plumbing systems so the risk is expected to be rare. However, opportunistic pathogen infections from plumbing systems do occur at times.	The risk needs discussion to decide whether it is acceptable. It is noted that short deadlegs already exist within existing plumbing systems, and many don't have any backflow prevention as proposed with the FPAA101D standard. It is probable that on balance the risk is not significantly higher than the risk associated with conventional plumbing systems. Nonetheless, given the high consequence rating for this risk, the risk requires special deliberation.	Single out this risk for special consideration.
Deadlegs feeding sprinklers	Toxigenic chemical hazards from plumbing fittings, e.g. copper, lead, cadmium, chromium or plastics leached from plumbing deadlegs.	Over time the concentrations of toxicants that may leach from pipes, or form in corrosion products, could reach levels that exceed guideline values in deadlegs. The AS/NZS 4020:2018 requirements only assure protection for pipes that are adequately turned over. If the water **backflows** into the potable system persons may be exposed via ingestion.	B	3	High	2.5.3.2.1 Sprinkler pipework deadlegs/stagnant water. The sprinkler system pipework shall be designed and installed so that no part of any pipework containing stagnant water is more than 3 m in lineal length. 2.5.3.2.3 Backflow prevention. A backflow prevention device in accordance with Clause 5.3.2 shall be installed on the sprinkler pipework... 2.5.3.2.4 Connection to toilets. All toilets shall be connected and supplied directly from the sprinkler system...	D	2	Low	The proposed standard will increase the potential for toxicant to reach concentrations of concern by providing increased surface area and deadlegs resulting in a potentially high risk. The controls proposed mean that the length of deadleg pipework is minimsed, the risk of backflow is reduced, and the water running to the toilet will provide a buffer of water that is turned over between the deadleg pipework and the potable plumbing system. The controls will reduce, but not eliminate, the risk of toxicants reaching levels that exceed guideline values being ingested. With such short deadlegs, very limited exposures would occur, for isolated events, and typically with water that is evidently contaminated through colour, taste, particulates, or odour, and unlikely to be consumed in large quantities, and not foreseeably consumed for prolonged periods. In practice, whilst short term exceedances of chemical guideline values might arise, exposure periods would be too short, and exposures too infrequent, to present significant health consequences.	High level of confidence. The leaching and corrosion of substances from plumbing fittings is well understood.	The risk is acceptable and is at worst only marginally higher than the risk associated with conventional plumbing systems that already include low turnover plumbing lines and fittings, often without backflow prevention or length limitations on deadlegs.	None.
Deadlegs feeding sprinklers	Aesthetic hazards including elevated colour, particulates, taste or odour, leached from, or arising in, plumbing deadlegs.	Over time the concentrations of substances that may leach, form in biofilms, or arise in corrosion products could reach levels that are detectable as colour, particles, tastes or odours. The AS/NZS 4020:2018 requirements only assure protection for pipes that are adequately turned over. If the water **backflows** into the potable system persons may notice.	C	2	Moderate	2.5.3.2.1 Sprinkler pipework deadlegs/stagnant water. The sprinkler system pipework shall be designed and installed so that no part of any pipework containing stagnant water is more than 3 m in lineal length. 2.5.3.2.3 Backflow prevention. A backflow prevention device in accordance with Clause 5.3.2 shall be installed on the sprinkler pipework... 2.5.3.2.4 Connection to toilets. All toilets shall be connected and supplied directly from the sprinkler system...	D	2	Low	The proposed standard will increase the potential for substances to reach discernible concentrations by providing increased surface area and deadlegs resulting in a potentially moderate risk. The controls proposed mean that the length of deadleg pipework is minimsed, the risk of backflow is reduced, and the water running to the toilet will provide a buffer of water that is turned over between the deadleg pipework and the potable plumbing system. The controls will reduce, but not eliminate, the risk of substances reaching levels that are discernible. With such short deadlegs, very limited exposures would occur, for isolated events, and not foreseeably for prolonged periods.	High level of confidence. The leaching and corrosion of substances from plumbing fittings is well understood.	The risk is acceptable and is only marginally higher than the risk associated with conventional plumbing systems that already include low turnover plumbing lines and fittings, often without backflow prevention or length limitations on deadlegs.	None.

Process Step (from flow diagram)	Contaminants ('hazards')	How can the hazard be introduced or exacerbated as a result of the proposed FPAA101D standard? ('hazardous events')	Likelihood (A-E)	Severity (1 to 5)	Maximum Risk (no specific controls)	Controls ('preventive measures') that are proposed in FPAA101D	Residual Likelihood (A-E)	Residual Consequence (1 to 5)	Residual Risk (with proposed controls)	Notes on basis of the scoring	Uncertainty	Acceptability of risk	Follow up actions
Domestic plumbing line	Enteric pathogens including bacteria (e.g. *Salmonella* spp. and *Campylobacter* spp.), parasites (e.g. *Cryptosporidium* spp.) and viruses (e.g. norovirus).	These pathogens are only present in water contaminated with faecal matter or putrescing food waste. They are no more likely to be present in deadleg fire sprinkler lines than in any other plumbing since they do not typically persist or grow in potable water, but rather they gradually die off over time. If the water is **cross-connected** into the potable system persons may be exposed via ingestion.	E	1	Low	2.5.3.2.1 Sprinkler pipework deadlegs/stagnant water. The sprinkler system pipework shall be designed and installed so that no part of any pipework containing stagnant water is more than 3 m in lineal length. 2.5.3.3 Connection to other systems. Other than detailed in this Specification, no part of the sprinkler system shall be connected to any other service including drencher systems, wall wetting systems, hose reels or the like.	E	1	Low	Enteric pathogens are primarily derived from fresh faecal matter and are not specifically of concern in deadlegs or pipework. The relatively low nutrients found in potable water do not typically support the proliferation of enteric pathogens even in the absence of a disinfectant residual, e.g. in deadlegs. Significant concentrations of enteric pathogens capable of resulting in significant consequences are not presented by the proposed standard, even without any dedicated controls, resulting in a low maximum and residual risk.	High level of confidence. The source, fate and transport of enteric pathogens in water is well understood.	The risk is acceptable and is no higher than the risk associated with conventional plumbing systems that already include low turnover plumbing lines and fittings, often without special cross-connection controls or length limitations on deadlegs.	None.
Domestic plumbing line	Opportunistic pathogens including bacteria such as *Legionella* spp. and amoebae such as *Naegleria* spp. and Acanthamoeba spp.	These pathogens are present naturally in water. They proliferate to levels of concern in stagnant water, particularly where they can form biofilms (e.g. on pipe surfaces), in water lacking a disinfectant residual (e.g. in deadleg pipes) and in warm water (e.g. in the 20 to 50˚C temperature range). If the water is **cross-connected** into the potable system persons may be exposed, e.g. via inhalation, eye, nose or skin contact.	E	4	High	2.5.3.2.1 Sprinkler pipework deadlegs/stagnant water. The sprinkler system pipework shall be designed and installed so that no part of any pipework containing stagnant water is more than 3 m in lineal length. 2.5.3.3 Connection to other systems. Other than detailed in this Specification, no part of the sprinkler system shall be connected to any other service including drencher systems, wall wetting systems, hose reels or the like.	E	4	High	The proposed standard will increase the potential for proliferation of opportunistic pathogens by providing increased surface area and deadlegs resulting in a potentially very high risk. The controls proposed mean that the length of deadleg pipework is minimsed and the extent of pipework that could be connected to the potable plumbing system is minimised. The controls will reduce, but not eliminate, the risk of opportunistic pathogens diffusing or being drawn back into the potable plumbing system if a cross-connection occurs. The risk is further mitigated by the likelihood that the presence of stagnant water would be associated with elevated colour, particulates, taste or odour. The resulting residual risk remains rare in likelihood but could have a major localised impact if the controls fail.	Moderate level of confidence. The presence of deadlegs similar to those proposed is not uncommon in existing plumbing systems so the risk is expected to be rare. However, opportunistic pathogen infections from plumbing systems do occur at times.	The risk needs discussion to decide whether it is acceptable. It is noted that short deadlegs already exist within existing plumbing systems, and many don't have any cross connection prevention. It is probable that the risk is only marginally incrementally higher than the risk associated with conventional plumbing systems. Nonetheless, given the high consequence rating for this risk, the risk requires special deliberation.	Single out this risk for special consideration.
Domestic plumbing line	Toxigenic chemical hazards from plumbing fittings, e.g. copper, lead, cadmium, chromium or plastics leached from plumbing deadlegs.	Over time the concentrations of toxicants that may leach from pipes, or form in corrosion products, could reach levels that exceed guideline values in deadlegs. The AS/NZS 4020:2018 requirements only assure protection for pipes that are adequately turned over. If the water is **cross-connected** into the potable system persons may be exposed via ingestion.	E	3	Moderate	2.5.3.2.1 Sprinkler pipework deadlegs/stagnant water. The sprinkler system pipework shall be designed and installed so that no part of any pipework containing stagnant water is more than 3 m in lineal length. 2.5.3.3 Connection to other systems. Other than detailed in this Specification, no part of the sprinkler system shall be connected to any other service including drencher systems, wall wetting systems, hose reels or the like.	E	2	Low	The proposed standard will increase the potential for toxicants to reach concentrations of concern by providing increased surface area and deadlegs resulting in a potentially high risk. The controls proposed mean that the length of deadleg pipework is minimsed and the extent of pipework that could be connected to the potable plumbing system is minimised. The controls will reduce, but not eliminate, the risk of toxicants diffusing or being drawn back into the potable plumbing system if a cross-connection occurs. The risk is further mitigated by the likelihood that the presence of stagnant water would be associated with elevated colour, particulates, taste or odour. With such short deadlegs, very limited exposures would occur, for isolated events, and typically with water that is evidently contaminated through colour, taste, particulates, or odour, and unlikely to be consumed in large quantities, and not foreseeably consumed for prolonged periods. In practice, whilst short term exceedances of chemical guideline values might arise, exposure periods would be too short, and exposures too infrequent, to present significant health consequences.	High level of confidence. The leaching and corrosion of substances from plumbing fittings is well understood.	The risk is acceptable and is at worst only marginally higher than the risk associated with conventional plumbing systems that already include low turnover plumbing lines and fittings, often without length limitations on deadlegs.	None.
Domestic plumbing line	Aesthetic hazards including elevated colour, particulates, taste or odour, leached from, or arising in, plumbing deadlegs.	Over time the concentrations of substances that may leach, form in biofilms, or arise in corrosion products could reach levels that are detectable as colour, particles, tastes or odours. The AS/NZS 4020:2018 requirements only assure protection for pipes that are adequately turned over. If the water is **cross-connected** into the potable system persons may notice.	C	2	Moderate	2.5.3.2.1 Sprinkler pipework deadlegs/stagnant water. The sprinkler system pipework shall be designed and installed so that no part of any pipework containing stagnant water is more than 3 m in lineal length. 2.5.3.3 Connection to other systems. Other than detailed in this Specification, no part of the sprinkler system shall be connected to any other service including drencher systems, wall wetting systems, hose reels or the like.	D	2	Low	The proposed standard will increase the potential for substances to reach discernible concentrations by providing increased surface area and deadlegs resulting in a potentially moderate risk. The controls proposed mean that the length of deadleg pipework is minimsed and the extent of pipework that could be connected to the potable plumbing system is minimised. The controls will reduce, but not eliminate, the risk of toxicants diffusing or being drawn back into the potable plumbing system if a cross-connection occurs. The controls will reduce, but not eliminate, the risk of substances reaching levels that are discernible. With such short deadlegs, very limited exposures would occur, for isolated events, and not foreseeably for prolonged periods.	High level of confidence. The leaching and corrosion of substances from plumbing fittings is well understood.	The risk is acceptable and is only marginally higher than the risk associated with conventional plumbing systems that already include low or no turnover plumbing lines and fittings, often without length limitations on deadlegs.	None.

Process Step (from flow diagram)	Contaminants ('hazards')	How can the hazard be introduced or exacerbated as a result of the proposed FPAA101D standard? ('hazardous events')	Likelihood (A-E)	Severity (1 to 5)	Maximum Risk (no specific controls)	Controls ('preventive measures') that are proposed in FPAA101D	Residual Likelihood (A-E)	Residual Consequence (1 to 5)	Residual Risk (with proposed controls)	Notes on basis of the scoring	Uncertainty	Acceptability of risk	Follow up actions
Toilet	Opportunistic pathogens including bacteria such as *Legionella* spp. and amoebae such as *Naegleria* spp. and Acanthamoeba spp.	These pathogens are present naturally in water. They proliferate to levels of concern in stagnant water, particularly where they can form biofilms (e.g. on pipe surfaces), in water lacking a disinfectant residual (e.g. in deadleg pipes) and in warm water (e.g. in the 20 to 50˚C temperature range). When water is **supplied to the toilet** persons may be exposed via inhalation of aerosols during flushing.	C	4	Very High	2.5.3.2.1 Sprinkler pipework deadlegs/stagnant water. The sprinkler system pipework shall be designed and installed so that no part of any pipework containing stagnant water is more than 3 m in lineal length.	E	4	High	The proposed standard will increase the potential for proliferation of opportunistic pathogens by providing an opportunity for such pathogens to grow in the incresaed surface area in deadlegs that could in turn influence water reaching toilets. The controls proposed mean that the length of deadleg pipework is minimsed. The controls will reduce, but not eliminate, the risk of opportunistic pathogens diffusing or being drawn into the toilet plumbing system. The resulting residual risk remains rare in likelihood but could have a major localised impact if the controls fail.	High level of confidence. Opportunistic pathogen infections from aerosols require the generation of aerosols. Toilets do generate some small aerosols during flushing but do not generate suspected fine aerosols in large quantities.	The risk needs discussion to decide whether it is acceptable. It is probable that the risk is at worst only marginally higher than the risk associated with conventional plumbing systems that already include low turnover plumbing lines and fittings, often without length limitations on deadlegs. Nonetheless, given the high consequence rating for this risk, the risk requires special deliberation.	Single out this risk for special consideration.