

Water Supply Peaking Factor Stochastics and Multiple Levels of Service

Taking advantage of stochastic peaking factors to reduce the cost of water supply infrastructure

L Donaldson

ABSTRACT

The availability of stochastic peaking factors allows water supply systems to be analysed much more thoroughly than when only a single value peaking factor is used. A particular application of stochastic peaking factors is for the sizing of water supply distribution pipes. Distribution pipes can be sized to serve multiple purposes such as supply pressure and continuity of supply using different levels of service, and in turn different peaking factors. Cost savings in excess of 15% may result for trunk distribution mains using multiple levels of service as compared to the conventional single peaking factor approach.

This application is dependent on there being agreed levels of service. Separate levels of service appropriate for water supply distribution for pressure and continuity of supply are proposed based on historical precedents and in particular the Hunter Water version of the Water Supply Code of Australia, WSA 03. An algorithm is proposed for setting levels of service which take into account the importance of the supply area.

Key Words: Water supply; Peaking factor; Stochastic; Level of service, Continuity of supply.

INTRODUCTION

The companion paper, *Water Supply Peaking Factor Stochastics*, L. Donaldson (2018), outlines the preparation of

the 100, 50, 20, 10, 5, 2 and 1-year recurrence interval Maximum Day and 30 Day peaking factors for south east Queensland area supply areas with average day demands between 0.1 and 600 ML/d.

This paper discusses the application of those stochastic peaking factors for the sizing of trunk distribution pipes using multiple levels of service. However, the selection of a stochastic peaking factor for such applications has no meaning unless there is also a link to a desired recurrence interval, i.e. a Level of Service (LOS). The first part of this paper therefore discusses setting appropriate LOS standards for water supply infrastructure.

LEVEL OF SERVICE

The LOS concept is often used by Australian water supply authorities for setting outage and repair time standards for distribution infrastructure. It is also used for setting water security objectives. In this paper the LOS concept is used for setting two water supply infrastructure standards:

- Supply pressure; and
- Continuity of supply

However, LOS standards do not currently exist, or are poorly defined, for these infrastructure standards. Proposals for setting those standards follow:

Supply Pressure

It is common to adopt a MD peaking factor of about 2 for water distribution investigations. Table 1 is reproduced from the paper *Water Supply Peaking Factor Stochastics* and

shows (shaded grey) for a typical supply area of up to about 6 ML/d (about 30,000 persons) that a peaking factor of 2 provides a return interval of roughly between about once in 2 and once in 5 years.

Table 1: South East Queensland MD Peaking Factors

RI (Year)	Supply Area Demand (ML/d)												
	0.1	0.3	0.5	0.7	0.9	1.4	2.7	6.1	14.4	35	74	192	597
1	1.80	1.50	1.44	1.39	1.35	1.35	1.35	1.42	1.45	1.43	1.42	1.39	1.38
2	2.50	1.90	1.76	1.69	1.62	1.60	1.57	1.62	1.63	1.57	1.54	1.48	1.45
5	3.86	2.60	2.29	2.17	2.07	2.01	1.91	1.92	1.89	1.79	1.71	1.62	1.54
10	5.37	3.29	2.80	2.64	2.49	2.38	2.22	2.18	2.12	1.96	1.85	1.73	1.62
20	7.46	4.16	3.42	3.20	3.00	2.82	2.58	2.48	2.38	2.16	2.00	1.85	1.70
50	11.52	5.69	4.46	4.12	3.82	3.54	3.14	2.94	2.76	2.45	2.22	2.01	1.81
100	16.00	7.20	5.45	5.00	4.60	4.20	3.65	3.35	3.10	2.70	2.40	2.15	1.90

In effect the adoption of a fixed peaking factor of 2 will result in a water supply's components increasing in standard as the supply area size increases. A more uniform approach for sizing infrastructure would be to supply the system infrastructure to a constant return interval. This approach is taken in the Hunter Water edition of the Water Supply Code WSA 03 (WSAA, 2009). That code provides peak day demand peaking factors used for distribution pressure investigations where the peak day values are expected to occur *about every two years on average*.

The peaking factors in Table 1, and the Hunter Water precedent, suggests that a 2-year recurrence interval would be a suitable LOS standard for designing infrastructure to meet pressure requirements. It is noted that in the current Hunter Water code, that LOS standard does not over-rule Appendix F of AS2419.1 - Fire Hydrant Installations for pressure requirements.

Continuity of Supply

Achievement of continuity of supply is clearly more important than maintenance of a minimum supply pressure. Guidance for setting an appropriate LOS standard for continuity of supply can be taken from several sources:

- The Hunter Water edition of the Water Supply Code WSA 03 (WSAA, 2009) provides both peak day and extreme day demand peaking factors. The extreme day demand peaking factors are expected to *occur about every 10 to 15 years on average* and are used by the Hunter Water code for determining both continuity of supply and reservoir storage requirements.
- An analysis of 83 Australian water supply authority water interruption rates (Bureau of Meteorology, 2017) for the 10-year period 2006-07 to 2015-16 found a 50 percentile rate of 10.3 years, and 30 and 70 percentiles of respectively 15.6 and 6.8 years. Those interruption rates have generally been acceptable to consumers.
- Van Zyl EJ et al (2008), after undertaking a stochastic analysis of consumer demands, *proposed that one failure in 10 years under seasonal peak conditions is used as a design criteria* for the sizing of storage tanks.

It is therefore suggested that 10 years is adopted as a minimum LOS standard for sizing infrastructure for continuity of supply purposes. The pressure requirements when achieving that standard would approach those deemed to be near the minimum for provision of a workable supply. A precedent for that provision is the 12 metre minimum pressure head required by the Hunter Water code (WSAA, 2009) under extreme demand conditions.

It is noted that some authorities allow lower pressures in fire-fighting situations. For example, the Queensland Planning Guidelines for Water Supply and Sewerage (Department of Energy and Water Supply, 2010), define service pressures for fire-fighting emergencies as *12m head measured in the main (relative to estimated ground level) at the hydrant, and 6m head in the main for all other areas of the water supply zone to ensure a minimum level of service to other customers during a fire event*. An alternative or perhaps additional LOS might therefore be, say, a 20-year LOS in conjunction with the 6 metre minimum head as suggested by that guideline.

While the 10-year level of service is proposed to be a minimum standard, the LOS for any supply area should be expected to rise in response to the increased economic and political consequences of a loss of supply. It is suggested such consequences could be measured by a combination of the residential population representing the residential community, and the equivalent non-residential population representing the commercial and industrial community. Selection of an appropriate level of service might then be guided by equation (1):

$$\text{Level of Service} = 10 \times e^{\text{Affected Supply Area Score}} \quad (1)$$

where the *Affected Supply Area Score* is calculated by summing the residential population divided by 600,000, and the equivalent person non-residential population divided by 125,000. While equation (1) and these weightings are clearly arbitrary, their selection results in the LOS gradually rising from a minimum of 10 years as the supply area's importance increases.

Table 2 sets out some examples of the application of the algorithms discussed above for the determination of LOS standards. The intent of the table is to demonstrate that the algorithms, albeit built on arbitrary weightings, provide a gradual increase in LOS with upward changes in supply area populations but rising to over 100 years to reflect the importance of supply to large population centres.

Table 2: Examples of LOS Calculation

Residential Population	Non-residential Population	LOS (Years)
1,000	200	10.0
5,000	1,200	10.2
30,000	60,000	17.0
1,000,000	100,000	118

APPLICATION OF MULTIPLE PEAKING FACTORS

Multiple Level of Service Criteria

The two LOS criteria to be applied when considering multiple peaking factors for water distribution pipes are:

- *Minimum supply pressure requirements* – A minimum head of 22 metres is provided in conjunction with a 2-year return interval peaking factor.
- *Continuity of supply* – A minimum head of 12 metres is provided in conjunction with at least a 10-year return interval peaking factor.

These two criteria can be compared to the conventional approach to only consider pressure requirements and to achieve a minimum head, commonly 22 metres, in conjunction with a peaking factor of, commonly, 2. That peaking factor, as previously discussed, approximates to about a 5-year recurrence interval.

Table 3 is a truncated version of Table 1 which has been prepared to compare the multiple LOS and conventional approaches.

Table 3: Multiple Levels of Service and Conventional MD Peaking Factors

RI (Year)	Supply Area Demand (ML/d)												
	0.1	0.3	0.5	0.7	0.9	1.4	2.7	6.1	14.4	35	74	192	597
<i>Multiple Levels of Service</i>													
2	2.50	1.90	1.76	1.69	1.62	1.60	1.57	1.62	1.63	1.57	1.54	1.48	1.45
10	5.37	3.29	2.80	2.64	2.49	2.38	2.22	2.18	2.12	1.96	1.85	1.73	1.62
<i>Conventional</i>													
≈ 5	2	2	2	2	2	2	2	2	2	2	2	2	2

The Multiple Level of Service (1 in 2 year RI) and Conventional (1 in 5 year RI) approaches are both required to achieve a minimum of pressure of 22 metres and it is clear from Table 3 that the 2-year RI peaking factors associated with a Multiple Level of Service approach are almost always less than the fixed peaking factor associated with the Conventional approach. The Multiple Level of Service approach would therefore be expected to result in a smaller diameter pipe when sizing for minimum pressure requirements.

But it is not immediately clear which approach would result in the smaller diameter when sizing for continuity of supply. The 10-year RI peaking factors associated with the Multiple Level of Service approach are higher than those for the Conventional approach but only a 12 metre head needs to be achieved as compared to the 22 metre head required for the Conventional approach. It therefore generally appears from Table 3 that the Multiple Level of Service approach would result in a smaller pipe diameter in situations where the respective peaking factors are not greatly different, and the pipe is operating under a relatively low head where the difference between the 12 and 22 metre head requirements for the two approaches makes a significant impact on the pipe hydraulics. A combination of those situations would most likely be associated with pipes of greater than 300 mm diameter which serve as trunk distributors.

Multiple Level of Service Case Study

In this case study a multiple level of service was applied to the investigation for the replacement of a 3 km long 590 mm trunk main which had reached the end of its economic life. The trunk main supplies an area servicing a 19,200 residential and 4,500 non-residential population with an average day demand of 5.9 ML.

Figure 1 shows the study area pipe layout and its pipe sizes including the 590 mm diameter trunk main to be replaced.

The multiple LOS criteria applied for case study were as follows:

- *Minimum supply pressure requirements* – A minimum head of 22 metres is needed to be achieved with a 2-year return interval. A peaking factor of 1.61 was interpolated from Table 1.
- *Continuity of supply* – A minimum head of 12 metres is needed to be achieved with a 10.7-year return interval. That return interval was calculated after applying equation (1) to the residential and non-residential populations. A peaking factor of 2.21 was interpolated from Table 1.

A separate assessment was also undertaken to determine the pipe sizes needed if the system was sized based on a conventional single MD peaking factor of 2 (approximately equivalent to a 5-year recurrence interval) to achieve a minimum head of 22 metres.

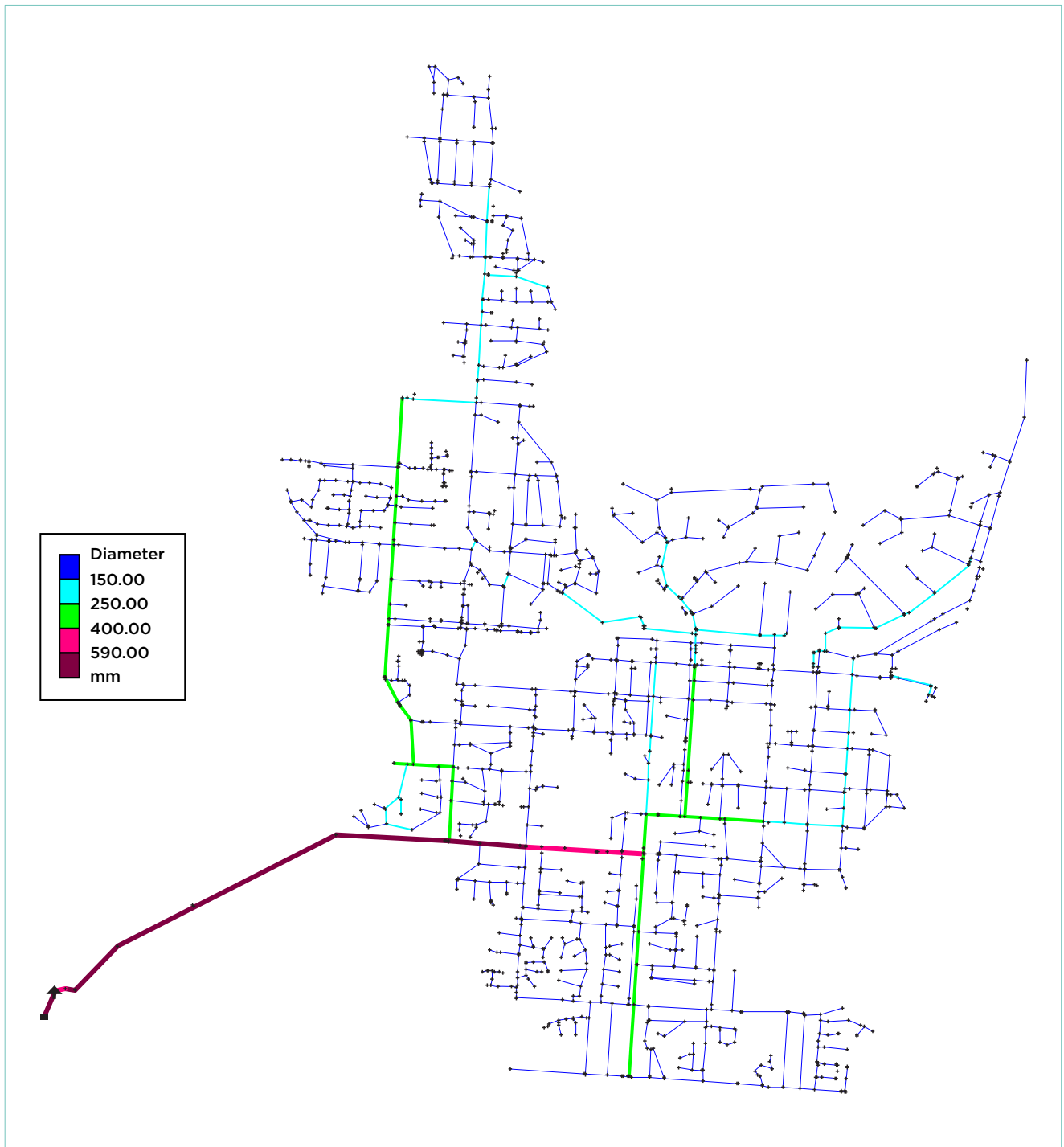


Figure 1: Case Study Supply Area and Pipe Sizes

A summary follows for the hydraulic modelling outcomes for the multiple level of service and conventional design criteria:

Multiple Level of Service Design

- Replacement pipe = 3,007 metres 486 mm dia. DICL
- Minimum system pressure for peaking factor 1.61 (minimum pressure LOS) = 22.7 m
- Minimum system pressure for peaking factor 2.21 (continuity of supply LOS) = 15.6 m

Conventional Design

- Replacement pipe = 3,007 metres 538 mm dia. DICL
- Minimum system pressure for peaking factor 2 = 22.7 m

Fire-fighting pressure requirements were still achievable with both pipe replacement options.

The estimated costs of the same length 486 mm diameter (Multiple Level of Service design) and 538 mm diameter (Conventional design) DICL pipes were respectively \$3.74 million and \$4.36 million. There was therefore a potential cost saving of about \$0.6 million, or about 17% of the Conventional cost, if a Multiple Level of Service approach was taken for this pipe replacement project.

CONCLUSIONS

The availability of stochastic peaking factors allows distribution pipes to be sized to match their purpose of use. It is suggested that meeting supply pressure requirements needs only have a 2-year level of service whereas continuity of supply should have a minimum of a 10-year level of service. However, the service pressure achieved while meeting continuity of supply requirements can be lower than the normal minimum pressure standards and a 12 meter minimum is proposed.

The adoption of a multiple level of service approach using these two criteria is expected to be more cost effective than the current conventional approach of adopting a single fixed demand criterion for trunk distribution mains. The sizing of smaller distribution/reticulations mains is not expected to result in smaller diameter pipes using a multiple LOS approach. A case study undertaken to compare the benefits impact of adopting a multiple level of service has shown that cost savings of about 17% for the study area's trunk mains would be possible to achieve as compared to using a conventional single peaking factor approach.

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THE AUTHOR



Lee Donaldson

Lee has investigated stochastic methods for the reliability analysis of water supply distribution systems using both optimisation and hydraulic modelling techniques.

Those methods have also included the development of the relationships between tank storage volumes, inflow rates and demand persistence. He has been engaged by several south-east Queensland water supply authorities to assess their failure risks with the aim of minimising storage volumes, and in turn system water age.

Email: lee.donaldson@bigpond.com