Manly Hydraulics Laboratory

FIRE AND RESCUE NSW FIRE HYDRANT TESTING 2017

Report MHL2534
February 2018

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Cover Photograph: Fire truck during testing

Fire and Rescue NSW
Fire Hydrant Testing

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Foreword

NSW government's professional specialist advisor, Manly Hydraulics Laboratory (MHL) was commissioned by Fire and Rescue NSW (FRNSW) to test the capacity of fire hydrant delivery of flows, at varying water pressures and combinations of fire truck booster pumping and firehoses.

The work is to inform FRNSW how to improve fire brigade access to fire-fighting water from reticulated water mains systems. In addition, the test scope was revised to include testing with 64 mm hoses as used by other fire-fighting agencies in Australia.

Executive summary

Fire and Rescue NSW (FRNSW) commissioned Manly Hydraulics Laboratory (MHL) to undertake testing of several configurations of hydrants, standpipes, and fire hoses to gain a greater understanding of the head-losses associated with this equipment, and to assess the minimum residual pressures required at the feed fire hydrant for a flow of 10 litres per second (l/s) being supplied to FRNSW fire-fighting pumping appliances.

Australian Standard 2419.1-2005 Fire Hydrant Installations nominates the minimum unassisted residual pressure required at the feed fire hydrant. In NSW, this is currently 150kPa for each fire hydrant required to flow at not less than 10 l/s. In all other states and territories this value is 200 kPa.

To investigate the aforementioned items, three types of tests were undertaken as follows:

1. Type A tests - hydrant supply to fire-fighting pumping appliances, where water supplied directly from the mains flows through hydrants and standpipes to fire appliance via fire hose, then pressurised by the fire pump via fire hose(s) with or without branch nozzles attached to the hose outlets.

2. Type B tests - open-ended hose testing, where water supplied directly from the mains flowed through hydrants and standpipes via open-ended fire hose(s).

3. Type C tests - head-loss testing of components, including the pressure drop from the water mains to the outlet of the feed hydrants.

Testing was undertaken with and without a *1 to 2 breeching piece* and with single and twin Ø70 mm canvas hoses as used by FRNSW. For completeness, Ø64 mm lay-flat canvas hose (without breeching piece), as used by most other fire-fighting agencies in Australia, was also assessed.

As part of this testing, other interested groups and fire-fighting agencies from across Australia were invited to witness the testing on a demonstration day.

The following photographs illustrate the fire-fighting water stream at 10l/s.

Photograph: 10 l/s water stream issuing from an FRNSW Ø65mm Akron branch via a single Ø64mm x 30m of lay-flat canvas hose

Photograph: 10 l/s water stream issuing from 2 x FRNSW Ø38mm Akron branches via twin lines Ø38mm x 30m of lay-flat canvas hoses

For the various laboratory test rig arrangements adopted, it was observed that to provide 10 l/s through a FRNSW pumping appliance, between 40 kPa and 80 kPa is required at the feed hydrant to maintain a positive pressure at the pump's collector gauge. Please note however, the actual required residual pressure (on-site measured gauge pressure) will vary according to the in-field conditions and is impacted by factors such as relative elevation between the feed hydrant and the pumping appliance, as well as fittings and hose arrangements.

Open ended hose testing showed that a 150 mm main with a ball valve hydrant and standpipe, and a standpipe gauge pressure of 150kPa, can unassisted, deliver 18.4 l/s through a single 70 mm hose, and 17.9 l/s through a single Ø64 mm hose, with hose outlets 1.53m below the standpipe gauge.

Key laboratory test result assumptions including pressure gauge elevations are documented for all tests. The test results will assist FRNSW assess minimum feed hydrant residual pressure requirements, considering factors such as site elevations, pump cavitation, hose collapse and maintaining positive pressures.

Testing of firefighting components showed approximate flow based headloss (hl) estimates in kilopascals (kPa), for flowrates (Q) in litres per second (l/s), as follows:

Headloss (kPa)	**Component**
$hl = 0.23 \times Q^2$	Water main to the outlet of a FRNSW standpipe
$hl = 0.14 \times Q^2$	Water main to the outlet of a FRNSW double delivery piece
$hl = 0.02 \times Q^2$	FRNSW 1 into 2 breeching (both outlets open)
$hl = 0.07 \times Q^2$	FRNSW 1 into 2 breeching (single outlet open)
$hl = 0.38 \times Q^2$	Single length of FRNSW Ø70mm x 30m canvas lay-flat hose
$hl = 0.43 \times Q^2$	Single length of RFS Ø64mm x 30m canvas lay-flat hose

Further test results including standard headloss resistance coefficients (k) are documented in the report.

Hydrant testing was performed under laboratory conditions. Real application situations will include variation in fire-fighting equipment and water supply arrangements. These can include the physical condition of pumps, valves, pipes and hoses; the relative elevation of supply infrastructure, hydrants and pumping appliances; and, water reticulation supply/pressure variability.

To support the development of firefighting standards, it is recommended that equipment lifecycle hydraulic performance variability is considered in line with testing, inspection, maintenance and replacement programs.

In-field testing equipment can be used to confirm headloss characteristics of individual property firefighting supply arrangements.

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1. Introduction

1.1 Background

Currently, Fire and Rescue NSW (FRNSW) are working to improve fire brigade access to firefighting water from the reticulated water mains system.

Discussions have raised questions with regards to Table 2.2 of *AS 2419.1-2005 Fire Hydrant Installations*, where in NSW the minimum unassisted residual pressure at the feed hydrant is currently 150kPa for each hydrant to flow simultaneously at 10 l/s.

It is noted in Table 2.2 of AS 2419.1-2005, that in "all other states and territories" the corresponding minimum unassisted required residual pressure is 200 kPa at the feed hydrant for each hydrant required to flow simultaneously at 10 l/s.

The historical reasoning behind the residual pressure figures nominated at the feed hydrant is not altogether clear.

FRNSW requested MHL to test and report on this residual pressure, to assist FRNSW in determining the appropriate minimum residual pressure at the feed hydrant to meet its operational requirements. The testing aims to assist both firefighting and water utility organisations develop informed firefighting water requirements.

1.2 Test scope

MHL's test scope presented in this report is as follows:

1. Develop a hydrant flow test rig and demonstrate its suitability.
2. Laboratory testing to investigate minimum residual pressures at the feed hydrant required to meet the operational needs of FRNSW. Various combinations of hydrants, standpipes, breach arrangements, hoses (straight and kinked, open ended, or feeding fire-fighting pump appliances) are tested.
3. Headloss determined in various components of the fire-fighting delivery system, including estimations of hydraulic resistance coefficients.
4. Reporting of results.

FRNSW described tests and confirmed test plans to meet its operational needs. FRNSW witnessed tests to ensure firefighting operational needs were met. FRNSW also provided firefighting equipment for the tests (fire truck/s, hoses and fittings).

MHL's *Know the Flow* testing facilities adapted for the fire hydrant testing are used for NATA tests, however, the tests presented in this report are non-NATA accredited tests due to the modification of the testing facilities and the adopted test methodology.

2. Methodology

This section presents a description of the equipment under test, a description of the test rig and the testing methodology used. Test rig schematics presented in this section are provided by FRNSW.

2.1 Test rig description

The hydrant test rig was built in MHL's Know the Flow facility utilising a 150mm tee from the facility's pumped 750mm supply line. The variable speed pump and valve arrangement, enabled test rig flowrates to be less than approximately 10% of the 750mm supply main flowrates.

The hydrant test section itself, consisted of a 150 mm flanged pipe line incorporating an electromagnetic flow meter for flow measurement, tappings for pressure measurements a 150 mm "T" piece to fit either a spring valve hydrant, or screw valve hydrant. Figure 2-1 outlines the test rig arrangement.

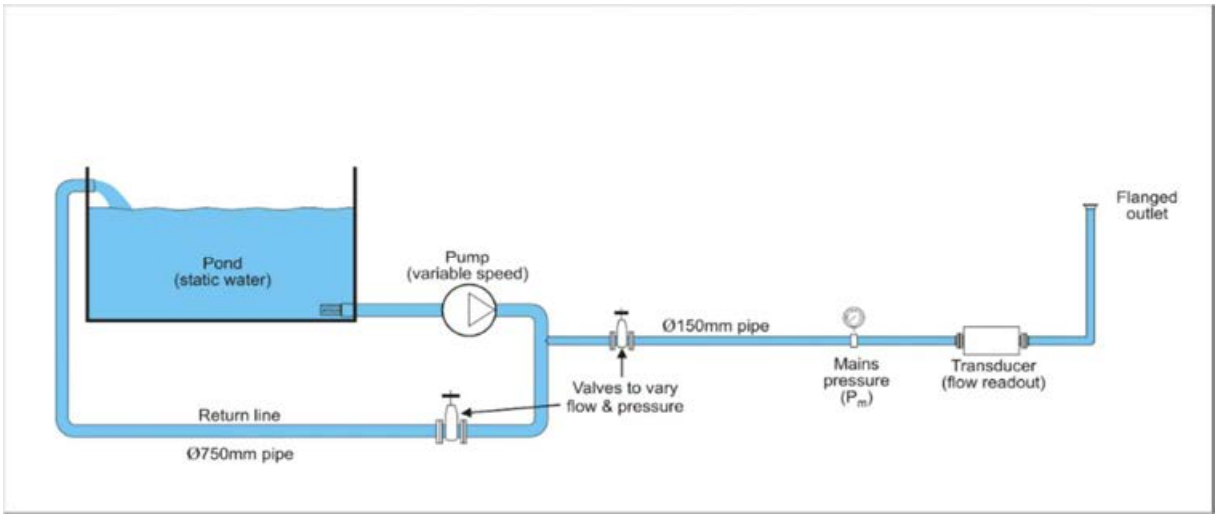

Figure 2-1: Test rig schematic

Sections of the test rig where fitted with a Ø65 mm Storz connector (supplied by FRNSW) placed between the standpipe and hoses to minimise hydraulic disturbances for pressure measurement (refer to Figure 2-2).

Figure 2-2: Pressure measurement section

A pressure gauge upstream of the 150 mm magnetic flow meter was used to define the supply main's water pressure. Two additional pressure gauges were used, one at the standpipe and one as the hose connected to the fire truck. Figure 2-3 to Figure 2-5 illustrate various test arrangements.

Figure 2-3: Hydrant supply to fire-fighting pumping appliance

Figure 2-4: Open ended hose test (kinked)

Figure 2-5: Headloss testing

Pressure gauges were levelled in (elevation) against a local datum (top of ponds wall at RL 0.00m). All MHL instruments were in calibration at the time of testing. Table 2-1 lists instruments used in testing. Instrument reduced levels are provided with the test results, where relevant.

Table 2-1: Instruments and relevant reduced levels

Test instrument	Instrument	Range	Units
Flow	ABB 150 mag Meter	0 - 80	l/s
Mains pressure gauge	Pressure gauge	-100 -1600	kPa
Mains pressure gauge	Pressure gauge	0 - 1600	kPa
Stand pipe pressure gauge	Pressure gauge	0 - 1500	kPa
Stand pipe pressure gauge	Pressure gauge	0 - 160	kPa
Collector pressure gauge	Pressure gauge	0 - 160	kPa
Headloss (differential) gauge	Pressure gauge	0 - 6	kPa
Headloss (differential) gauge	Pressure gauge	0-160	kPa
Truck compound pressure gauge[1]	Fire truck BB 35 JX	-100 - 1600	kPa
Truck compound pressure gauge[1]	Fire truck BG 30 RB	-100 - 1600	kPa

1. Non-calibrated gauge.

2.2 Test equipment

The equipment tested was supplied by FRNSW, NSW Rural Fire Services and Sydney Water Corporation (SWC). Table 2-2 lists the equipment tested, and identifies the owner of the equipment.

Table 2-2: Equipment being tested

No	Description	Owner
2	Fire trucks with booster pumps and collector gauges, registrations BB 35 JX and BG 30 RB	FRNSW
5	Sections of Ø70 mm canvas hose (30m long)	FRNSW
5	Sections of Ø64 mm canvas hose (30m long)	NSW Rural Fire Services
1	Ball valve hydrant	SWC
1	Screw valve hydrant	SWC
1	Standpipe	FRNSW
1	1 to 2 breeching piece	FRNSW
1	Double delivery piece with Storz outlets	FRNSW

During testing both the standpipe and the double delivery were fully open and then turned back ¼ of a turn.

Appendix A provides images of the test equipment.

2.3 Test plan

Three basic types of tests were undertaken:

1. Type A tests - hydrant supply to fire-fighting pumping appliances, where water supplied directly from the mains flows through hydrants and standpipes to fire appliance via fire hose, then pressurised by the fire pump via fire hose(s) with or without branch nozzles attached to the hose outlets.

2. Type B tests - open-ended hose testing, where water supplied directly from the mains flowed through hydrants and standpipes via open-ended fire hose(s).

3. Type C tests - head-loss testing of components, including the pressure drop from the water mains to the outlet of the feed hydrants.

The test plan was modified as the tests proceeded, according to FRNSW's test needs. Table 2-3 describes the tests, including the test number adopted in this report and the equivalent test number from FRNSW proposed test plans dated 10 and 31 March 2017. Testing was undertaken as follows:

- **Test rig proof of concept**: 24 February 2017.
- **Test Day 1** was held on 22 March 2017 using the older Commander fire appliance. The data collected corresponding with FRNSW's document titled, *Formal Recommended Tests report* dated 10 March 2017. Observed by FRNSW and SWC representatives.

- **Test Day 2** (rehearsal day) was held on 3 April 2017 using a Scania fire appliance. The data collected corresponding with FRNSW's document titled, *Formal Recommended Tests report (Ver 01)* dated 31 March 2017. Observed by FRNSW and SWC representatives.
- **Test Day 3** (demonstration day) was held on 5 April 2017, again using the Scania fire appliance, but with a new compound gauge fitted. Observed by multiple interested parties.
- **Test Day 4** head loss testing on 6 April 2017 through a double delivery and screw valve hydrants.

Table 2-3: Test plan

Test No.	Description	Test date
-	Test rig - proof of concept	24/02/2017
A1	Measure maximum flowrates achievable to a pumper with residual pressure at the standpipe held at 150kPa. Single line and length of FRNSW Ø70mm x 30m canvas lay-flat hose between the standpipe and the collector of the fire pump. FRNSW 1 into 2 breeching fitted in line with single hose. Truck BB 35 JX (Commander).	22/03/2017
A2	Measure maximum flowrates achievable to a pumper with residual pressure at the standpipe held at 150kPa. Twin lines of single length of FRNSW Ø70mm x 30m canvas lay-flat hose between the standpipe and the collector of the fire pump. FRNSW 1 into 2 breeching fitted in line with twin hoses. Truck BB 35 JX (Commander).	22/03/2017
A3	Measure maximum flowrates achievable to a pumper with residual pressure at the standpipe held at 150kPa. Single line and length of FRNSW Ø70mm x 30m canvas lay-flat hose between the standpipe and the collector of the fire pump. Truck BG 30 RB (Scania).	3/04/2017
A4	Measure maximum flowrates achievable to a pumper with residual pressure at the standpipe held at 150kPa. Single line and length of RFS Ø64mm x 30m canvas lay-flat hose between the standpipe and the collector of the fire pump. Truck BG 30 RB (Scania).	3/04/2017
A5	Measure minimum workable residual pressure required at the standpipe to achieve a flow of 10 l/s through a fire pump. Single line and length of RFS Ø64mm x 30m canvas lay-flat hose between the standpipe and the collector of the fire pump. Truck BG 30 RB (Scania).	5/04/2017
A6	Measure minimum workable residual pressure required at the standpipe to achieve a flow of 10 l/s through a fire pump. Single line of FRNSW Ø70mm x 30m canvas lay-flat hose between the standpipe and the collector of the fire pump. Truck BG 30 RB (Scania).	03/04/17

Test No.	Description	Test date
B1	Measure maximum flow available with residual pressure at the standpipe held at 150kPa via open ended hoses back to pond for: • a single line of FRNSW Ø70mm x 30m canvas lay-flat hose, with FRNSW 1 into 2 breeching included • twin lines of FRNSW Ø70mm x 30m canvas lay-flat hose.	22/03/2017
B2	Measure minimum residual pressure required at the standpipe to cause the nominated flow via open ended hoses back to pond for: • 10 l/s via a single length of FRNSW Ø70mm x 30m canvas lay-flat hose, • 20 l/s via twin lines of FRNSW Ø70mm x 30m canvas lay-flat hose.	22/03/2017
B3	Measure maximum flow available with residual pressure at the standpipe held at 150kPa via open ended hoses back to pond for: • a single length of FRNSW Ø70mm x 30m canvas lay-flat hose, • a single length of RFS Ø64mm x 30m canvas lay-flat hose.	3/04/2017
B4	Measure minimum residual pressure required at the standpipe to cause flow of 10 l/s via open ended hoses back to pond for: • a single length of FRNSW Ø70mm x 30m canvas lay-flat hose, & • a single length of RFS Ø64mm x 30m canvas lay-flat hose, & • a single length of RFS Ø64mm x 30m canvas lay-flat hose (kinked & valves not from previous test), • a single length of RFS Ø64mm x 30m canvas lay-flat hose (kinked with valves adjust back to 10 l/s).	3/04/2017
C1	Determine the flow resistance constant “k” from the connection point in the main, through the spring valve hydrant, through to the outlet of a FRNSW standpipe.	3/04/2017
C2	Determine the flow resistance constant “k” across a FRNSW *1 into 2* breeching for: • both outlets of breeching open, and • single outlet of breeching open.	6/04/2017
C3	Determine the flow resistance constant “k” along a single length of FRNSW Ø70mm x 30m canvas lay-flat hose.	3/04/2017
C4	Determine the flow resistance constant “k” along a single length of RFS Ø64mm x 30m canvas lay-flat hose.	3/04/2017
C5	Determine the flow resistance constant “k” from the connection point in the main, through the screw valve hydrant, through to the outlet of the FRNSW double delivery.	6/04/2017

The demonstration day on 5 April 2017 was provided for interested parties. This included representatives from:

- Fire and Rescue NSW
- Sydney Water Corporation
- Country Fire Association
- ACT Fire and Rescue
- Queensland Fire and Rescue Services
- Queensland Urban Utilities
- Melbourne Fire Brigade (Victoria)
- Association of Hydraulic Engineers
- Australasian Fire and Emergency Service Authorities Council
- Rural Fire Services (NSW).

2.4 Test descriptions

2.4.1 Proof of concept

Twin 70 mm hose through a breeching piece run straight to the ponds to demonstrate proof of concept of the test rig. Figure 2-6 shows the set-up for the proof of concept for the test rig.

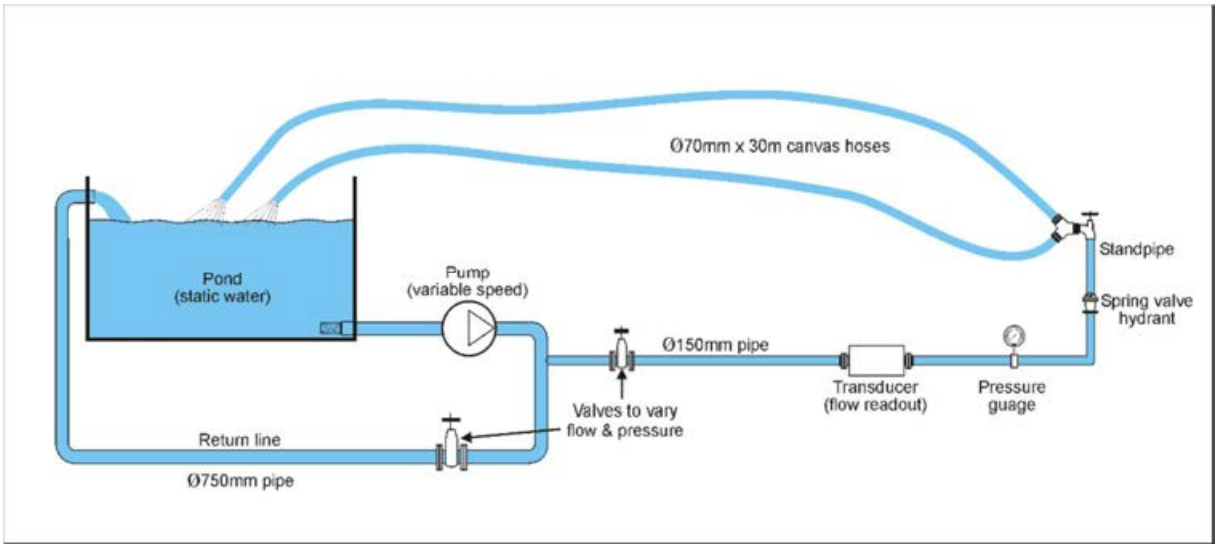

Figure 2-6: Proof of concept test rig

2.4.2 Tests A1-A6: Hydrant supply to fire-fighting pumping appliances

Set the test rig up as shown in Figure 2-1, with and without the 1 into 2 breeching, and with and without the branches on the end of the delivery hose(s).

These tests enable combinations of stepped fire truck boosting, whilst maintaining a positive standpipe gauge pressure (Ps), as well as testing to pump cavitation and/or hose collapse.

For each step in pump operation, flowrates, pressures at the standpipe gauge and compound gauge “Pcg”, and fire truck pump RPM are measured. Refer to Figure 2-7 for the test set-up.

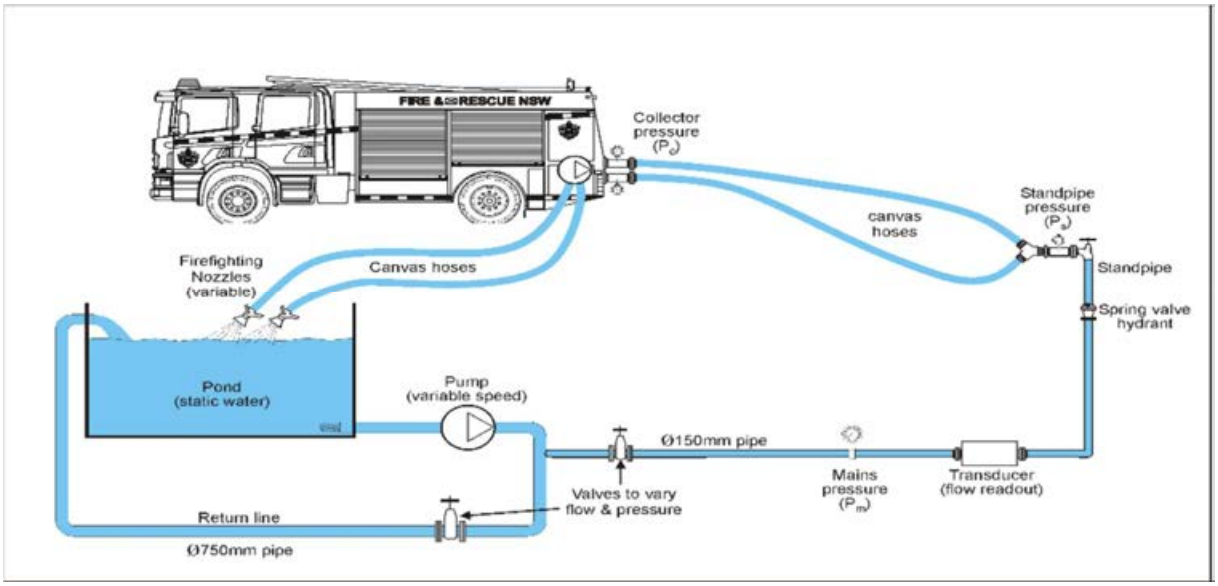

Figure 2-7: General drawing for hydrant supply to fire-fighting pumping appliance testing

2.4.3 Tests B1 – B4: Open-ended hose testing

Set the test rig up as shown in Figure 2-9, with and without the 1 into 2 breeching, and with and without the branches on the end of the delivery hose(s).

These tests enable unassisted direct hydrant flows and pressures to be measured. Refer to Figure 2-8 for the test set-up.

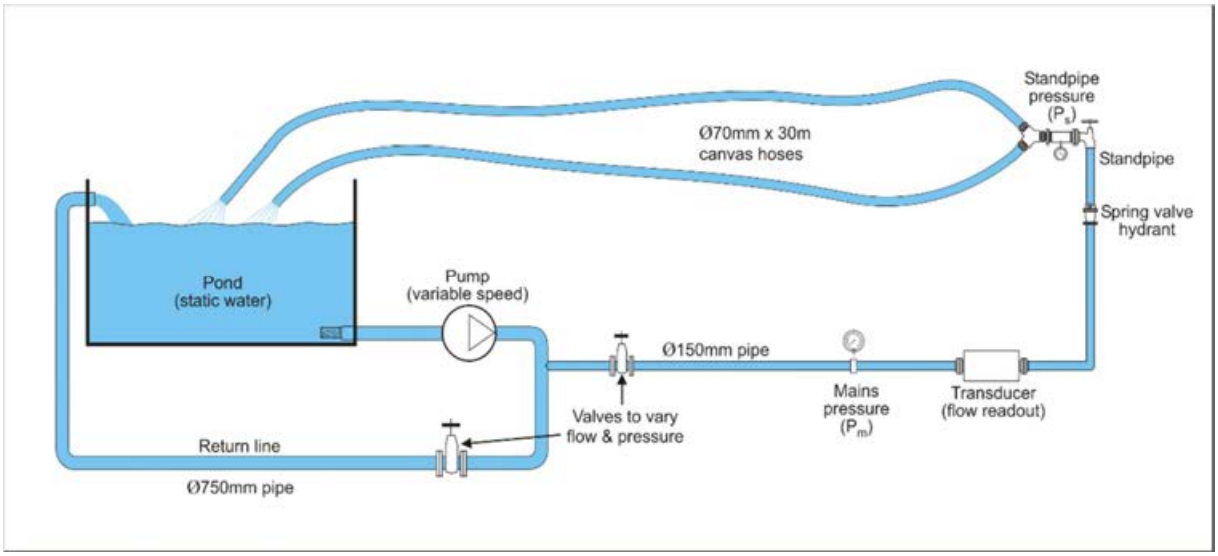

Figure 2-8: General drawing for open-ended hose testing

2.4.4 Tests C1-C5: headloss testing of components and hoses

Various test rig arrangements were established to enable measurement of headloss and flow across equipment. Resistance coefficients are determined from these measurements.

Spring valve hydrant/FRNSW standpipe and screw valve hydrant testing

With water flowing in the rig as shown in Figure 2-9, adjust the flow from zero up to 30 l/s in steps of 2.5 l/s whilst recording the corresponding differential pressure between pressure gauges (Pm) & (Ps) for each step in flow.

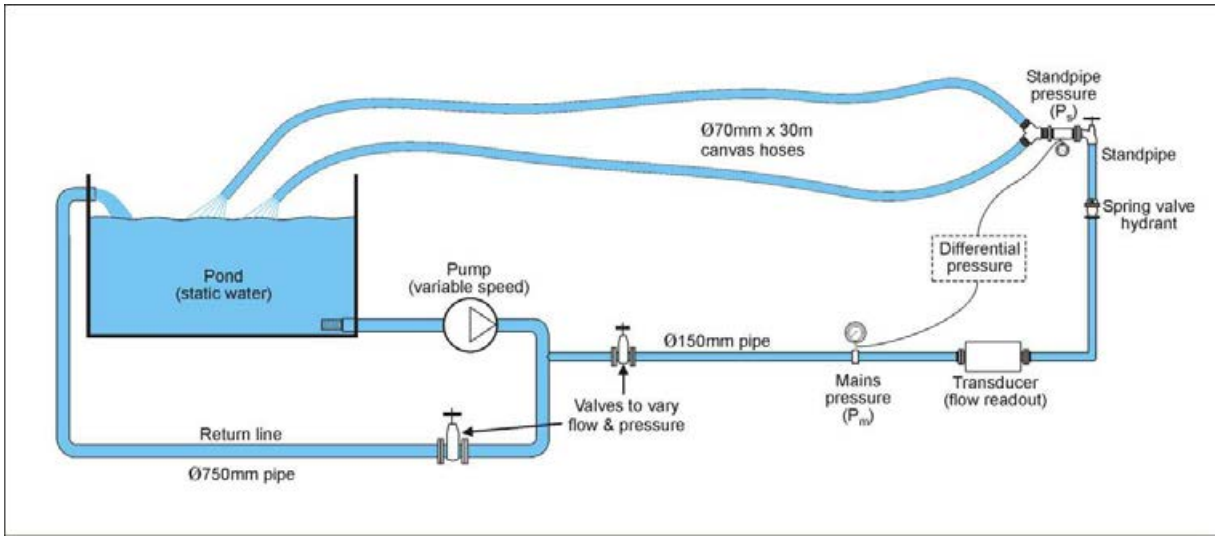

Figure 2-9: Test C1 and Test C5 set-up

Breeching headloss testing

Figure 2-10 shows the test setup to determination the flow resistance constant “k” across a FRNSW 1 into 2 breeching. With water flowing via both outlets of the 1 into 2 breeching, adjust the flow from zero up to 30 l/s in steps of 2.5 l/s, whilst recording the differential pressure measured from the standpipe (Ps) to the outlet of the breeching (Pb) for each step in flow, and include these values in the table provided. Repeat with one breeching closed.

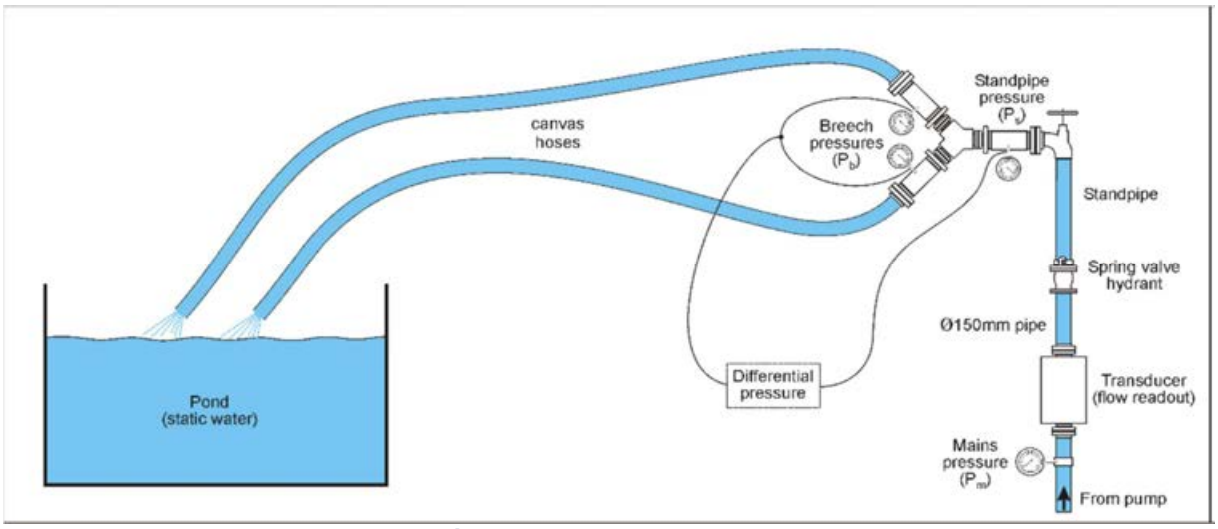

Figure 2-10: Test C2 set-up

Hose headloss testing

With water flowing through 5 lengths of straight hose (in series) of FRNSW Ø70mm x 30m (for Test C3) or Ø64mm x 30m (for Test C4) and canvas lay-flat hose, adjust the flow from zero up to 20 l/s in steps of 2.5 l/s whilst recording the corresponding pressure at pressure gauge “P1” for each step in flow (see Figure 2-11). Note: the outlet of the last hose is open to atmosphere, with no additional flow restriction attached.

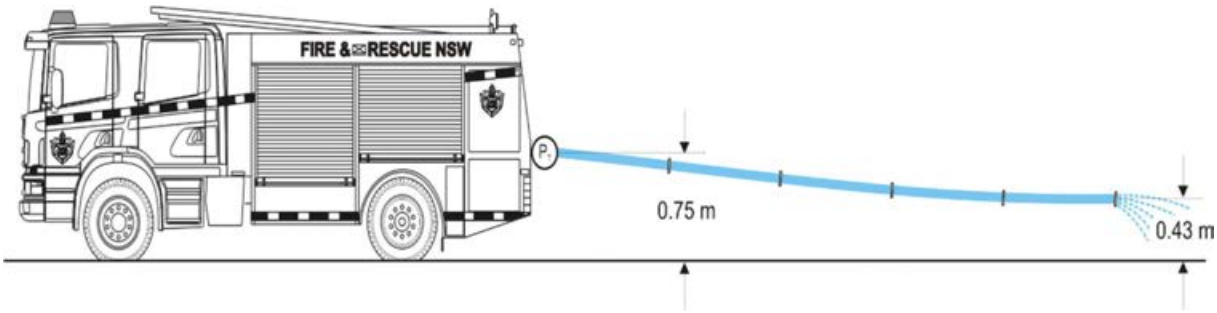

Figure 2-11: Test C3 and Test C4 set-up

Double delivery headloss testing

Install the screw valve hydrant and double delivery system, use two NSWFR Ø70mm x 30m hose. With water flowing in the rig as shown in Figure 2-9, adjust the flow from zero up to 30 l/s in steps of 2.5 l/s whilst recording the corresponding differential pressure between pressure gauges (Pm) & (Ps) for each step in flow.

2.5 Hydraulic terminology and headloss calculations

In this report the following hydraulic definitions, based mainly on *Internal Flow Systems* (Miller, 1990) are used:

- *Hydraulic head* (pressure head or piezometric head) – The head above a datum to which fluid rises in a tube connected to a tapping in a pipe or passage, or the water level in a reservoir. It can be represented graphically as the *hydraulic grade line* (HGL).
- *Velocity head* – given by $V^2/2g$, where V is the average velocity of flow in a pipe and g is the acceleration due to gravity.
- *Total head* – the sum of the hydraulic head and velocity head. It can be represented graphically as the *energy line* (EL).
- *Headloss* – The difference in total head between two points related to a common datum.
- *Gauge pressure* – the pressure above or below local atmospheric pressure.

Residual pressure is the water pressure measured in a point within a system at a particular flow rate (AS 2419).

Pressure test results are reported in kilopascals (kPa), head test results in meters of water head (mH2O), and flowrate in litres per second (l/s). Estimated flow headloss coefficients are also provided where relevant.

To simplify the inclusion of hydraulic devices into larger systems, headloss is sometimes presented as a coefficient of velocity head, a *resistance coefficient* known as the *k*-value.

From:

$$\underbrace{z_1 + \frac{p_1}{\rho g} + \frac{v_1^2}{2g}}_{EnergyIn} = \underbrace{z_2 + \frac{p_2}{\rho g} + \frac{v_2^2}{2g}}_{EnergyOut} + \underbrace{hl}_{EnergyLost}$$

$$hl = Energy_{In} - Energy_{Out} = k\frac{v^2}{2g}$$

where:

z_1 and z_2 is the elevation of gauge above a datum in metres at point 1 and point 2 respectively

p_1 and p_2 is the pressure at point 1 and 2 respectively (kPa)

ρ is the density of the water

g is the acceleration due to gravity

v_1 and v_2 is the velocity at point 1 and 2 respectively

hl is the headloss (energy lost in the system).

To assist firefighters, FRNSW requested an approximate flowrate based headloss coefficient identified as "k_Q" in this report:

$$hl = k_Q \times Q^2$$

where:

Q is flow rate (l/s)

hl is the headloss in kPa.

k_Q a flow headloss coefficient constant for the particular component.

3. Results

This section presents results of the testing. Refer to Table 2-3 and section 2.4 for the detailed description of each test.

Table 3-1 summarises key assumptions common to each test.

Table 3-1: Key test assumptions

Key assumptions	Value	Units
Acting gravity 'g'	9.79672	m/s^2
Water density	1000	kg/m^3
Pressure at outlet (open to atmosphere)	0.000	kPa
150mm dia. mains area	0.01767	m^2
70mm dia. hose area	0.00385	m^2
64 mm dia. hose area	0.00332	m^2
Mains diameter	0.150	m
Hose diameter remains constant across the flow rates		

Proof of concept test results are provided in Appendix B for information.

Note: Initial Day 1 testing (22/3/17) was found to have been compromised by a damaged hose coupling (crushed internal lining tongue) on one of the FRNSW Ø70mm x 30m canvas lay-flat hoses. In the pumping appliance tests it was also observed that there was more pressure in one line than the other, suggesting issues with the pump valves. Tests A1, A2, B1 and B2 are impacted. These test results are provided in Appendix B for completeness and information only.

Figure 3-1 and Figure 3-2 illustrate the fire-fighting water stream at 10 l/s.

Figure 3-1: 10 l/s water stream- FRNSW Ø64mm Akron branch - single Ø64mm x 30m of lay-flat canvas hose

Figure 3-2: 10 l/s water stream - 2 x FRNSW Ø38mm Akron branches - twin lines Ø38mm x 30m of lay-flat canvas hoses

3.1 Hydrant supply to fire-fighting pumping appliances tests

3.1.1 Test A1 and A2

Damaged test equipment. Refer to Appendix B for information.

3.1.2 Test A3

To measure maximum flowrates achievable to a pumper with residual pressure at the standpipe held at 150kPa. Single line and length of FRNSW Ø70mm x 30m canvas lay-flat hose between the standpipe and the collector of the fire pump. Truck BG 30 RB (Scania), Results are presented in Table 3-2.

Table 3-2: Test A3 results

Measurement point	Units	Measurements							
Flow	l/s	11.2	12.3	13.4	14.1	15.1	15.8	16.8	17.3
Mains gauge pressure (P_m)	kPa	170	190	195	200	205	210	210	210
Mains hydraulic head	mH_2O	17.5	19.6	20.1	20.6	21.1	21.6	21.6	21.6
Standpipe gauge pressure (P_s)	kPa	150	150	150	150	150	150	150	150
Standpipe hydraulic head	mH_2O	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8
Collector gauge pressure (P_c)	kPa	100	90	80	70	60	50	40	30
Collector hydraulic head	mH_2O	10.8	9.8	8.7	7.7	6.7	5.7	4.7	3.6
Truck compound gauge	kPa	100	90	80	30	-15	-33	-53	-62
Fire pump speed	RPM	2440	2790	3020	3215	3420	3620	3950	4150
Mains gauge height	m	0.176							
Standpipe gauge height	m	1.527							
Collector gauge height	m	0.583							

The test was stopped when the pump collector gauge reached 30 kPa due to the on-set of cavitation in the pump of the firefighting appliance.

3.1.3 Test A4

To measure maximum flowrates achievable to a pumper with residual pressure at the standpipe held at 150kPa. Single line and length of RFS Ø64mm x 30m canvas lay-flat hose between the standpipe and the collector of the fire pump. Truck BG 30 RB (Scania). Results are presented in Table 3-3.

Table 3-3: Test A4 results

Measurement point	Units	Measurements								
Flow	l/s	10.8	11.9	12.6	13.6	14.3	15	15.9	16.5	17.2
Mains gauge pressure (P_m)	kPa	160	180	190	195	200	205	210	210	215
Mains hydraulic head	mH_2O	16.5	18.5	19.6	20.1	20.6	21.1	21.6	21.6	22.1
Standpipe gauge pressure (P_s)	kPa	150	150	150	150	150	150	150	150	150
Standpipe hydraulic head	mH_2O	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8
Collector gauge pressure (P_c)	kPa	100	90	80	70	60	50	40	30	20
Collector hydraulic head	mH_2O	10.8	9.8	8.7	7.7	6.7	5.7	4.7	3.6	2.6
Truck compound gauge	kPa	110	100	90	70	-10	-25	-40	-55	-70
Fire pump speed	RPM	2330	2600	2800	3020	3210	3400	3600	3810	4100
Mains gauge height	m	0.176								
Standpipe gauge height	m	1.527								
Collector gauge height	m	0.583								

The test was stopped when the pump collector gauge reached 20 kPa due to the on-set of cavitation in the pump of the fire-fighting appliance.

3.1.4 Test A5

To measure minimum workable residual pressure required at the standpipe to achieve a flow of 10 l/s through a fire pump. Single line and length of RFS Ø64mm x 30m canvas lay-flat hose between the standpipe and the collector of the fire pump. Truck BG 30 RB (Scania). Results are presented in Table 3-4.

Table 3-4: Test A5 results

Measurement point	Units	Measurements					
Flow	l/s	10.0	9.6	9.8	10.0	10.0	10.0
Standpipe gauge pressure (P_s)	kPa	200	150	125	100	75	60
Standpipe hydraulic head	mH_2O	20.9	15.8	13.3	10.7	8.2	6.7
Collector gauge pressure (P_c)	kPa	150	100	80	50	25	0
Collector hydraulic head	mH_2O	15.9	10.8	8.7	5.7	3.1	0.6
Truck compound gauge	kPa	200	150	100	80	-20	-50
Fire pump speed	RPM	3015	3100	3200	3250	3400	3550
Mains gauge height	m	0.176					
Standpipe gauge height	m	0.527					
Collector gauge height	m	0.583					

Note: the standpipe gauge was lowered to approximately the feed hydrant level.

3.1.5 Test A6

To measure minimum workable residual pressure required at the standpipe to achieve a flow of 10 l/s through a fire pump. Single line of FRNSW Ø70mm x 30m canvas lay-flat hose between the standpipe and the collector of the fire pump. Fire truck BG 30 RB (Scania). Results are presented in Table 3-5.

Table 3-5: Test A6 results

Measurement point	Units		Measurements						
Flow	l/s	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Standpipe gauge pressure (P_s)	kPa	100	90	80	70	60	50	40	33
Standpipe hydraulic head	mH_2O	11.7	10.7	9.7	8.7	7.7	6.6	5.6	4.9
Collector gauge pressure (P_c)	kPa	66	56	45	34	21	12	2	0
Collector hydraulic head	mH_2O	7.3	6.3	5.2	4.1	2.7	1.8	0.8	0.6
Mains gauge height	m	0.176							
Standpipe gauge height	m	1.527							
Collector gauge height	m	0.583							

Note: the standpipe gauge was lowered to approximately the feed hydrant level.

3.2 Non-boosted flow tests

3.2.1 Test B1 and B2

Damaged test equipment. Refer to Appendix B for information.

3.2.2 Test B3

To measure maximum flow available with residual pressure at the standpipe held at 150kPa via open ended hoses back to pond for:

- a single length of FRNSW Ø70mm x 30m canvas lay-flat hose
- a single length of RFS Ø64mm x 30m canvas lay-flat hose.

Results are presented in Table 3-6.

Table 3-6: Test B3 results

Measurement point	Units	70 mm	64 mm
Flow	l/s	18.4	17.9
Standpipe gauge pressure (P_s)	kPa	150	150
Standpipe hydraulic head	mH_2O	16.8	16.8
Standpipe delivery pressure*	kPa	165	165
Hose outlet hydraulic head	mH_2O	0.0	0.0
Standpipe gauge height	m	1.527	
Hose outlet height	m	0.00	

* Driving pressure between the standpipe and end of hose, corrected for elevation

3.2.3 Test B4

To measure minimum residual pressure required at the standpipe to cause flow of 10 l/s via open ended hoses back to pond for:

- a single length of FRNSW Ø70mm x 30m canvas lay-flat hose
- a single length of RFS Ø64mm x 30m canvas lay-flat hose
- a single length of RFS Ø64mm x 30m canvas lay-flat hose (kinked & valves not from previous test)
- a single length of RFS Ø64mm x 30m canvas lay-flat hose (kinked with valves adjust back to 10 L/s).

Results are presented in Table 3-7.

Table 3-7: Test B4 results

Measurement point	Units	70mm hose smooth	64 mm hose smooth	64 mm hose kinked	64 mm hose kinked
Flow	l/s	10.0	9.9	6.5	10.5
Standpipe gauge pressure (P_s)	kPa	43	45	58	130
Standpipe hydraulic head	mH2O	5.9	6.1	7.4	14.8
Standpipe delivery pressure*	kPa	58	60	73	145
Hose outlet pressure	kPa	0.0	0.0	0.0	0.0
Hose outlet hydraulic head	mH2O	0.00	0.00	0.00	0.00
Standpipe gauge height	m	1.527			
Hose outlet height	m	0.00			

* Driving pressure between the standpipe and end of hose, corrected for elevation.

3.3 Headloss testing

Resistance coefficients (k) are based on the component's smaller internal diameter and noted with each results table (to enable headloss estimate calculations and avoid confusion when comparing component k values).

3.3.1 Test C1

To determine the flow resistance constant "k" from the connection point in the main, through the spring valve hydrant, and to the outlet of a FRNSW standpipe.

Results are presented in Table 3-8.

Table 3-8: Test C1 results (spring valve hydrant and standpipe)

Parameter	Units	Measurement											
Flow	l/s	2.5	5	7.5	10	12.5	14.8	18.3	19.9	22.5	25	26.7	27.4
Differential pressure	kPa	1.5	6	12	23	36	48	74	87	113	140	160	170
Differential head	mH2O	0.2	0.6	1.2	2.3	3.7	4.9	7.6	8.9	11.5	14.3	16.3	17.4
Feed main velocity	m/s	0.1	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.3	1.4	1.5	1.6
Feed main velocity head	mH2O	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Standpipe velocity	m/s	0.8	1.5	2.3	3.0	3.8	4.5	5.5	6.0	6.8	7.5	8.0	8.3
Standpipe velocity head	mH2O	0.0	0.1	0.3	0.5	0.7	1.0	1.6	1.8	2.3	2.9	3.3	3.5
Total head loss	mH2O	0.1	0.5	1.0	1.9	3.0	3.9	6.1	7.1	9.3	11.5	13.1	14.0
k_q	kPa/l/s	0.24	0.24	0.21	0.23	0.23	0.22	0.22	0.22	0.22	0.22	0.22	0.23
k	-	4.32	4.32	3.73	4.10	4.11	3.86	3.90	3.87	3.95	3.97	3.98	4.02
Average k_q	kPa/l/s	0.23											
Average k	-	4.0											

Note: k estimate based on 65 mm ID.

3.3.2 Test C2

Determine the flow resistance constant “k” across a FRNSW *1 into 2* breeching for

- both outlets of breeching open, and
- single outlet of breeching open.

Results are presented in Table 3-9.

Table 3-9: Test C2 results (breeching piece)

Parameter	units	Across Both sides of breeching								
Flow	l/s	0.0	2.5	5.0	7.5	10.0	12.5	15.1	17.5	19.8
Differential pressure	kPa	0	0.2	0.25	0.6	1.21	2.22	3.3	4.6	5.9
Differential head	mH2O	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.5	0.6
Standpipe velocity	m/s	0.0	0.8	1.5	2.3	3.0	3.8	4.6	5.3	6.0
Standpipe velocity head	mH2O	0.0	0.0	0.1	0.3	0.5	0.7	1.1	1.4	1.8
Breeching velocity	m/s	0.0	0.4	0.8	1.1	1.5	1.9	2.3	2.6	3.0
Breeching velocity head	mH2O	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5
Total head loss	mH2O	0.0	0.0	0.1	0.3	0.5	0.8	1.1	1.5	2.0
kq	kPa/l/s	0.00	0.03	0.01	0.01	0.01	0.01	0.01	0.02	0.01
k*	-	0.00	1.45	0.97	0.98	1.02	1.06	1.07	1.08	1.08
Mean kq	kPa/l/s	0.02								
Mean k*	-	1.09								
Across only one side of breaching										
Flow	l/s	0.0	2.5	5.2	7.6	10.0	12.5	15.0	16.1	
Differential pressure	kPa	0	0.6	1.5	3.7	6.2	11	17	21	
Differential head	mH2O	0.0	0.1	0.2	0.4	0.6	1.1	1.7	2.1	
Standpipe velocity	m/s	0.0	0.8	1.6	2.3	3.0	3.8	4.5	4.9	
Standpipe velocity head	mH2O	0.0	0.0	0.1	0.3	0.5	0.7	1.0	1.2	
Breeching velocity	m/s	0.0	0.8	1.6	2.3	3.0	3.8	4.5	4.9	
Breeching velocity head	mH2O	0.0	0.0	0.1	0.3	0.5	0.7	1.0	1.2	
Total head loss	mH2O	0.0	0.1	0.2	0.4	0.6	1.1	1.7	2.1	
kq	kPa/l/s	0.00	0.10	0.06	0.06	0.06	0.07	0.08	0.08	
k*	-	0.00	2.26	1.22	1.41	1.37	1.55	1.66	1.78	
Mean kq	kPa/l/s	0.07								
Mean k*	-	1.61								

* k estimate based on breeching inlet – single 65mm ID, k and kq are variable depending on flowrates and are tabled. Flowrate should be considered when selecting the k/kq value.

3.3.3 Test C3

To determine the flow resistance constant “k” along a single length of FRNSW Ø70mm x 30m canvas lay-flat hose.

Results are presented in Table 3-10. Figure 2-11 shows relative elevations of the truck gauge and hose outlet.

Table 3-10: Test C3 results (70mm hose)

Item	Units	Measurements										
Flow	L/s	12.4	13.7	14.6	15.5	16.2	17.1	17.5	18.4	18.9	19.7	20.3
Truck gauge pressure	kPa	290.0	350.0	400.0	450.0	500.0	550.0	600.0	650.0	700.0	750.0	800.0
Hydraulic head at truck	mH2O	30.4	36.5	41.6	46.7	51.8	56.9	62.0	67.1	72.2	77.3	82.4
Gauge fitting velocity	m/s	3.7	4.1	4.4	4.7	4.9	5.2	5.3	5.5	5.7	5.9	6.1
Total head at gauge	mH2O	31.1	37.3	42.6	47.8	53.0	58.2	63.4	68.7	73.9	79.1	84.3
Hydraulic head at hose outlet	mH2O	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Hose velocity	m/s	3.2	3.6	3.8	4.0	4.2	4.4	4.5	4.8	4.9	5.1	5.3
Total head at hose outlet	mH2O	1.0	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.8	1.9
Hydraulic head loss over 5 lengths	kPa	293.1	353.1	403.1	453.1	503.1	553.1	603.1	653.1	703.1	753.1	803.1
Total headloss over 5 lengths	mH2O	30.1	36.3	41.4	46.5	51.7	56.8	61.9	67.1	72.2	77.3	82.5
Average headloss per length	mH2O	6.0	7.3	8.3	9.3	10.3	11.4	12.4	13.4	14.4	15.5	16.5
kq (5 lengths)	kPa/l/s	1.91	1.88	1.89	1.89	1.92	1.89	1.97	1.93	1.97	1.94	1.95
k (5 lengths)	unitless	56.8	56.1	56.4	56.2	57.1	56.4	58.7	57.5	58.6	57.8	58.1
For Single Length												
kq	kPa/l/s	0.38	0.38	0.38	0.38	0.38	0.38	0.39	0.39	0.39	0.39	0.39
k	unitless	11.36	11.21	11.27	11.24	11.43	11.27	11.74	11.50	11.73	11.57	11.61
Mean kQ	kPa/l/s	0.38										
Mean k	-	11.45										

Note: k estimate based on 70mm ID hose. k_Q based on truck gauge pressure reading. Flowrate should be considered when selecting the k value.

3.3.4 Test C4

To determine the flow resistance constant “k” along a single length of RFS Ø64mm x 30m canvas lay-flat hose. Figure 2-11 shows relative elevations of the truck gauge and hose outlet.

Results are presented in Table 3-11.

Table 3-11: Test C4 results (64 mm hose)

Item	Units	Measurements										
Flow	L/s	10.5	12.3	13.2	14.5	15.3	16.1	16.8	17.6	18.3	18.9	19.6
Truck gauge pressure	kPa	240.0	330.0	380.0	460.0	500.0	550.0	600.0	650.0	700.0	750.0	800.0
Hydraulic head at truck	mH2O	25.2	34.4	39.5	47.7	51.8	56.9	62.0	67.1	72.2	77.3	82.4
Gauge fitting velocity	m/s	3.2	3.7	4.0	4.4	4.6	4.9	5.1	5.3	5.5	5.7	5.9
Total head at gauge	mH2O	25.8	35.1	40.3	48.7	52.9	58.1	63.3	68.5	73.8	79.0	84.2
Hydraulic head at hose outlet	mH2O	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Hose velocity	m/s	3.2	3.7	4.0	4.4	4.6	4.9	5.1	5.3	5.5	5.7	5.9
Total head at hose outlet	mH2O	0.9	1.1	1.2	1.4	1.5	1.6	1.7	1.9	2.0	2.1	2.2
Hydraulic head loss over 5 lengths	kPa	243.1	333.1	383.1	463.1	503.1	553.1	603.1	653.1	703.1	753.1	803.1
Total headloss over 5 lengths	mH2O	24.8	34.0	39.1	47.3	51.4	56.5	61.6	66.7	71.8	76.9	82.0
Average headloss per length	mH2O	5.0	6.8	7.8	9.5	10.3	11.3	12.3	13.3	14.4	15.4	16.4
kq (5 lengths)	kPa/l/s	2.20	2.20	2.20	2.20	2.15	2.13	2.14	2.11	2.10	2.11	2.09
k (5 lengths)	unitless	48.6	48.5	48.4	48.5	47.3	47.0	47.1	46.4	46.2	46.4	46.0
For Single Length												
kq	kPa/l/s	0.44	0.44	0.44	0.44	0.43	0.43	0.43	0.42	0.42	0.42	0.42
k	unitless	9.71	9.70	9.68	9.70	9.47	9.40	9.41	9.29	9.25	9.29	9.21
Mean kQ	kPa/l/s	0.43										
Mean k	-	9.46										

Note: k estimate based on 64 mm ID hose. k_Q based truck gauge pressure reading. Flowrate should be considered when selecting the k/kq value.

3.3.5 Test C5

To determine the flow resistance constant “k” from the connection point in the main, through the screw valve hydrant, through to the outlet of the FRNSW double delivery.

Results are presented in Table 3-12.

Table 3-12: Test C5 results (screw valve hydrant)

Parameter	Units	Measurements											
Flow	l/s	2.5	4.9	7.4	9.9	12.4	15	17.5	19.9	22.5	24.9	27.5	28.1
Differential pressure	kPa	1	4	8	14	21	30	40	51	66	80	98	103
Differential head	mH2O	0.1	0.4	0.8	1.4	2.1	3.1	4.1	5.2	6.7	8.2	10.0	10.5
Feed main velocity	m/s	0.1	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.3	1.4	1.6	1.6
Feed main velocity head	mH2O	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Standpipe velocity	m/s	0.8	1.5	2.2	3.0	3.7	4.5	5.3	6.0	6.8	7.5	8.3	8.5
Standpipe velocity head	mH2O	0.0	0.1	0.3	0.5	0.7	1.0	1.4	1.8	2.3	2.9	3.5	3.7
Total head loss	mH2O	0.1	0.3	0.6	1.0	1.5	2.1	2.7	3.4	4.5	5.4	6.6	7.0
kq	kPa/l/s	0.16	0.17	0.15	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13
k	-	2.56	2.70	2.25	2.18	2.04	1.97	1.91	1.87	1.91	1.88	1.89	1.91
Mean kq	kPa/l/s	0.14											
Mean k	-	2.09											

Note: k estimate based on 64 mm ID. Double delivery valve was leaking. Flowrate should be considered when selecting the k/kq value.

4. Conclusions and recommendations

The laboratory testing documented in this report provides information to assist FRNSW with an improved understanding of hydrant water pressure requirements to provide effective firefighting flows. Testing of the 64 mm hoses can assist other fire-fighting agencies in understanding their required water pressures at the feed fire hydrant to achieve effective fire-fighting flows.

Key laboratory test result assumptions including pressure gauge elevations are documented for all tests. The test results will assist FRNSW assess minimum feed hydrant residual pressure requirements, considering factors such as site elevations, pump cavitation, hose collapse and maintaining positive pressures.

Further test results including standard headloss resistance coefficients (k) are documented in the report.

Hydrant testing was performed under laboratory conditions. Real application situations will include variation in fire-fighting equipment and water supply arrangements. These can include the physical condition of pumps, valves, pipes and hoses; the relative elevation of supply infrastructure, hydrants and pumping appliances; and, water reticulation supply/pressure variability.

To support the development of firefighting standards, it is recommended that equipment lifecycle hydraulic performance variability is considered in line with testing, inspection, maintenance and replacement programs.

In-field testing equipment can be used to confirm headloss characteristics of individual property firefighting supply arrangements.

5. References

AS 2200-2006: Design charts for water supply and sewerage

AS 24191.1-2005: Fire Hydrant Installations – System Design, Installation and Commissioning

Miller, DS, 1990, Internal Flow Systems, Second Edition, BHRA (Information Services), The Fluid Engineering Centre, Cranfield, UK.

Appendix A – Test equipment

Figure A-1: Fire Truck BB 35 JX (Commander)

Figure A-2: Fire Truck BG 30 RB (Scania)

Figure A-3: Ball valve hydrant

Figure A-4: Screw valve hydrant

Figure A-5: Standpipe

Figure A-6: 1 to 2 breeching piece

Figure A-7: Double delivery with Storz outlets

Appendix B – Other test information

Proof of concept

Initial testing of the hydrant test arrangement, confirmed the stability of the test rig and its suitability for further hydrant based testing as presented in Table B-1 and Figure B-1.

Table B-1: Proof of concept test results

Data point	Mains pressure (kPa)	Flow Rate (l/s)
1	50	8.6
2	100	12.2
3	200	17.4
4	300	20.9
5	400	25.1
6	500	27.8
7	640	31.6

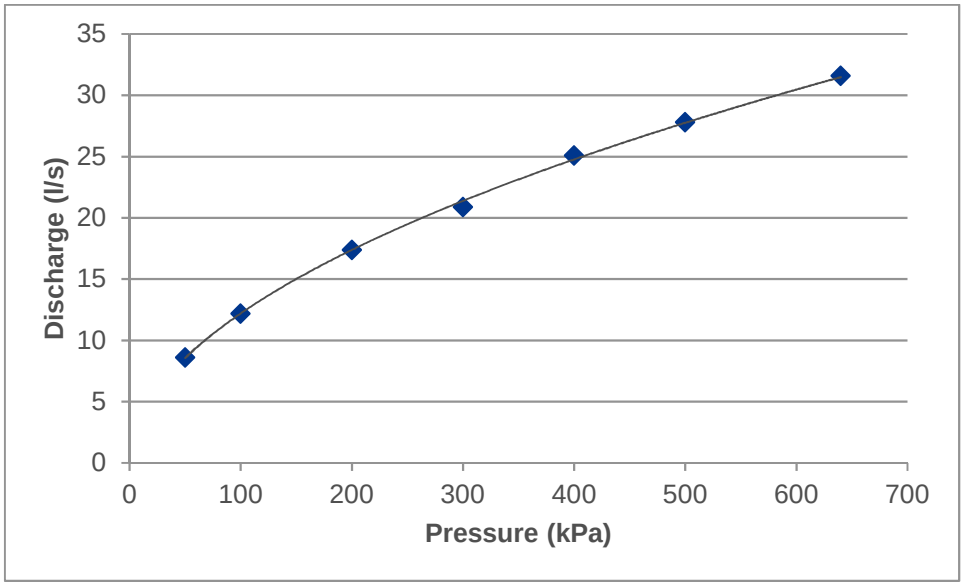

Figure B-1: Proof of concept test results

Day 1 testing (22/3/17)

Tests A1, A2, B1 and B2 results are compromised as it was later found one of FRNSW Ø70mm x 30m canvas lay-flat hoses was damaged coupling, with the tongue being crushed (see Figure B-2). It was also observed for pumping appliance tests that there was more pressure in one line than the other, suggesting issues with the pump valves. Test results are provided here for completeness and information only.

Figure B-2: Damaged hose coupling

Test A1 Results

To measure maximum flowrates achievable to a pumper with residual pressure at the standpipe held at 150kPa. Single line and length of FRNSW Ø70mm x 30m canvas lay-flat hose between the standpipe and the collector of the fire pump. FRNSW 1 into 2 breeching fitted in line with single hose. Truck BB 35 JX (Commander), results are presented in Table B-2.

Table B-2: Test A1 results

Measurement point	Units	Measurements						
Flow	l/s	7.9	9.4	10.2	10.3	11.5	12.8	14.2
Mains gauge pressure (P_m)	kPa	160	165	170	180	195	195	200
Mains hydraulic head	mH_2O	17.9	18.4	18.9	19.9	21.4	21.4	21.9
Standpipe gauge pressure (P_s)	kPa	150	150	150	150	150	150	150
Standpipe hydraulic head	mH_2O	16.7	16.7	16.7	16.7	16.7	16.7	0.0
Collector gauge pressure (P_c)	kPa	100	90	80	70	60	50	40
Collector hydraulic head	mH_2O	11.2	10.1	9.1	8.1	7.1	6.1	5.0
Mains gauge height	m	1.526						
Standpipe gauge height	m	1.427						
Collector gauge height	m	0.953						

Test A2 Results

To measure maximum flowrates achievable to a pumper with residual pressure at the standpipe held at 150kPa. Twin lines of single length of FRNSW Ø70mm x 30m canvas lay-

flat hose between the standpipe and the collector of the fire pump. FRNSW 1 into 2 breeching fitted in line with twin hoses. Truck BB 35 JX (Commander). Results are presented in Table B-3.

Table B-3: Test A2 results

Measurement point	Units	Measurements							
Flow	l/s	16.3	18.5	19.1	20.6	22.0	24.7	25.6	29.5
Mains gauge pressure (P_m)	kPa	205	205	210	240	255	290	320	345
Mains hydraulic head	mH_2O	22.5	22.5	23.0	26.0	27.6	31.1	34.2	36.7
Standpipe gauge pressure (P_s)	kPa	150	150	150	150	150	150	150	150
Standpipe hydraulic head	mH_2O	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7
Collector gauge pressure (P_c)	kPa	100	90	80	70	60	50	40	35
Collector hydraulic head	mH_2O	11.2	10.1	9.1	8.1	7.1	6.1	5.0	4.5
Mains gauge height	m	1.526							
Standpipe gauge height	m	1.427							
Collector gauge height	m	0.953							

Test B1 Results

To measure maximum flow available with residual pressure at the standpipe held at 150kPa via open ended hoses back to pond for:

- a single line of FRNSW Ø70mm x 30m canvas lay-flat hose, with FRNSW 1 into 2 breeching included
- twin lines of FRNSW Ø70mm x 30m canvas lay-flat hose.

Test results are presented in Table B-4.

Table B-4: Test B1 results

Measurement Point	Units	2 hoses	1 hose
Flow	l/s	31.9	15.0
Mains gauge pressure (P_m)	kPa	390	200
Mains hydraulic head	mH_2O	41.34	21.94
Standpipe gauge pressure (P_s)	kPa	150	150
Standpipe hydraulic head	mH_2O	16.74	16.74
Standpipe delivery pressure*	kPa	164	164
Hose outlet pressure	kPa	0.00	0.00
Hose outlet hydraulic head	mH_2O	0.00	0.00
Mains gauge height	m	1.53	
Standpipe gauge height	m	1.43	
Hose outlet	m	0.00	

*

Test B2 Results

To measure minimum residual pressure required at the standpipe to cause the nominated flow via open ended hoses back to pond for:

- 10 l/s via a single length of FRNSW Ø70mm x 30m canvas lay-flat hose,
- 20 l/s via twin lines of FRNSW Ø70mm x 30m canvas lay-flat hose.

Results are presented in Table B-5.

Table B-5: Test B2 results

Measurement Point	Units	2 Hoses		1 Hose	
Flow	l/s	20	10	16.2	10
Standpipe gauge pressure (P_s)	kPa	150	40	160	73
Standpipe hydraulic head	mH_2O	16.7	5.5	17.8	8.9
Standpipe delivery pressure	kPa	164	54	174	87
Hose outlet pressure	kPa	0.00	0.00	0.00	0.00
Hose outlet hydraulic head	mH_2O	0.00	0.00	0.00	0.00
Standpipe gauge height	m	1.427			
Hose outlet height	m	0.00			