Appendix D:

Statistical Analysis of Rainfall and Overflow Events

Memo

To:	Wolfgang Kanz & Neville West (GDC); Ian Mayhew & Megan Dever (4Sight)
From:	Bridget Bosworth, Environmental Monitoring & Hydrology
Date:	13-May-2020
Subject:	High level analysis of rainfall and scour events (2014-2019), Gisborne City

Analysis of rainfall and scour events (2014-2019), Gisborne city

This is a high level analysis of rainfall and scour events to establish if there is a pattern to when the scour valves have to be opened in Gisborne city. Scour valves have to be opened during heavy rain events when the wastewater network reaches its conveyance capacity due to high stormwater inflow. The aim of this assessment was to identify whether there was a clear correlation between rainfall duration/intensity and the opening of the scour valves.

The analysis comprises examination of:

- Rainfall events when the scours have to be opened (Part 1); and
- Rainfall events when the scours remain closed (Part 2).

For Part 1, sixteen rainfall events between April 2014 and February 2020 have been examined:

18-Apr-2014	4-Apr-2017	3-Sep-2017	6-Aug-2018
11-Jun-2014	13-Apr-2017	12-Mar-2018	7-Sep-2018
4-Aug-2014	12-May-2017	4-Jun-2018	13-Jun-2019
20-Sep-2015	29-May-2017	11-Jun-2018	15-Oct-2019

The scours had to be opened during fifteen of these events. One rainfall event (on 12-Mar-2018) was a wet weather background water quality check and the scours were not opened.

For Part 2, six non-overflow rainfall events were examined:

6-8 April 2014	4-6 November 2015	6-18 February 2017
15-17 March 2015	28 January 2016	29-30 December 2018

The rainfall data from five sites around Gisborne city were analysed. All the sites are owned and/or managed by Gisborne District Council (GDC). The sites are:

- Gisborne Airport Met Station;
- Paraone Rd RG (rain gauge);
- Stout Street RG;
- Waikanae Creek at Customhouse Street Bridge; and
- Wheatstone Rd.

A map of the rainfall recording sites has been included as Annex A.

Not all the events could be analysed using data from each rainfall site. Waikanae Creek at Customhouse Street Bridge was only established in April 2018 and GDC only has rainfall data at Gisborne Airport Met Station from July 2017.

An Average Recurrence Interval (ARI) (in years) was obtained for the rainfall data at each site (considering different durations) using the National Institute of Water and Atmospheric Research (NIWA)'s web-based programme, known as HIRDS (High Intensity Rainfall Design System) (version 4) (NIWA, 2017).

The HIRDS tables provide rainfall depths at any location in New Zealand for different durations (including 10 minutes, 20 minutes, 30 minutes, 1 hour, 2 hours, 6 hours, 12 hours, 1 day, 2 days and 3 days) and for different ARIs (including 1.58, 2, 5, 10, 20, 30, 40, 50, 60, 80, 100 and 250 years). Where rainfall at a site did not exactly match the rainfall depth for a given ARI, interpolation was used to estimate the ARI.

According to NIWA, "*HIRDS is not really designed for sub-annual return periods. This is because the processing…is all based on annual maxima time-series. This means that the extreme value distributions*…[used] *to estimate return periods/rainfall depths are undefined for return periods of 1 year or less*" (Dr Trevor Carey-Smith, Climate Scientist, NIWA, 2020, pers. comm., 26-Mar-2020).

This means that any ARI of 1 year or less provided in this memo in graphs and tables is only indicative and is not meaningful as an absolute value.

Part 1: Examination of rainfall events when scours have to be opened

Rainfall events and ARIs

Table 1 below provides a summary of the sixteen rainfall events examined in Part 1. The table includes the highest ARI recorded for each rainfall event (with its associated duration) and the site where it was recorded. Also included are general comments related to the rain event.

The rain gauge at Gisborne Airport was blocked in September 2018, so the data from this site were not accurate for the 7-Sep-2018 rain event.

Graphs for each event have been provided in Annex B. These show the ARIs for different durations at each site. Each graph has a red dotted line showing the 2 year ARI. A rain event could last for up to 3 days; the ARI for each duration is the ARI associated with the maximum rainfall recorded over that duration (whether that is 10 minutes, 6 hours or 2 days) within that three day period.

Table 1: Summary of rainfall events and scour analysis

Date	Highest ARI (years)	Duration	Site	Comments/notes
18-Apr-2014	12.9	12 hours	Paraone Rd	• Seven valves were opened across the city. • The first valve was opened at 10:20 on 18-Apr-2014. • At Stout St, the rain event started at 16:50 (NZST) on 17 April and lasted until 13:10 on 18 April. • Both intense (short duration) rainfall and heavy, prolonged rainfall (Paraone Rd and Stout Street). • Rainfall not significant at Wheatstone Rd. • No data from Gisborne Airport or Waikanae Creek.
11-Jun-2014	5.3	1 day	Stout St	• 12 valves were opened across the city. • The first valve was opened at 9:21 on 11-Jun-2014. • Rain started at 18:00 (NZST) on 10-Jun-2014. • Highest ARIs recorded for longer durations (12 hours and 1 day). • No data from Gisborne Airport or Waikanae Creek.
4-Aug-2014	10.4	1 day	Stout St	• 11 valves were opened across the city. • Intense rainfall (short durations) at Wheatstone Rd; heavy rainfall (long durations) at Stout St and Paraone Rd. • No data from Gisborne Airport or Waikanae Creek.
20-Sep-2015	9.8	1 day	Wheatstone Rd	• Eight valves were opened across the city. • At Wheatstone Rd, both high intensity (short duration) and heavy prolonged rainfall. • At Paraone Rd and Stout St, the longer durations (1, 2 and 3 days) have the highest ARIs. • No data from Gisborne Airport or Waikanae Creek.
4-Apr-2017	2.4	1 day	Paraone Rd	• Eight valves were opened across the city. • The first scour was opened at 16:11 on 4-Apr. • At Paraone Rd, the rain started at 7:35 (NZST) on 4-Apr-2017 and lasted until 3:10 (NZST) on 5-Apr-2017 • At Paraone Rd, the ARI was more than 2 years for the medium/long durations (6 hours, 12 hours, 1 day). • At Stout St the ARI was more than 2 years for the long duration (1 day). • The rainfall at Wheatstone Rd had an ARI of less than 2 years for all durations.

Date	Highest ARI (years)	Duration	Site	Comments/notes
				• No data from Gisborne Airport or Waikanae Creek.
13-Apr-2017	5.9	2 hours	Stout St	• Five valves had to be opened. • Based on the rain gauge data, the event appears to be localised. • Only the rainfall at Stout St has an ARI greater than 2 years – for both shorter (30 min, 1 hour) and medium (6 hour, 12 hour) durations. • No data from Gisborne Airport or Waikanae Creek.
12-May-2017	1.7	1 day	Wheatstone Rd	• Three valves had to be opened: Peel St/Palmerston Rd; Russell St; and Wainui Rd. • Rainfall not significant at any site. • No data from Gisborne Airport or Waikanae Creek.
29-May-2017	1.8	10 min	Paraone Rd	• Two valves had to be opened: Russell St and Wainui Rd. • Rainfall not significant at any site. • No data from Gisborne Airport or Waikanae Creek.
3-Sep-2017	1.7	20 min	Stout St	• One valve was opened (Wainui Rd). • Rainfall not significant at any site. • No data from Waikanae Creek.
12-Mar-2018	3.5	10 min	Gisborne Airport Met Station	• Scours/valves not opened; this was a wet weather background water quality check. • Relatively intense, localised rainfall (10 min duration) recorded at Gisborne Airport Met Station. For all other durations (and sites) the ARI was less than 2 years.
4-Jun-2018	3.8	20 min	Paraone Rd	• Two valves were opened (Wainui Rd and Seymour/Turenne). • Rainfall has an ARI of more than 2 years at Paraone Rd (short and medium durations) and Wheatstone Rd (short durations). • Rainfall was not significant at Gisborne Airport, Stout St and Waikanae Creek. • Based on the rainfall data, the rainfall event appears to be localised.
11-Jun-2018	1.5	1 day	Stout St	• Six valves had to be opened across the city. • Rainfall was not significant at any site.
6-Aug-2018	1.1	3 days	Paraone Rd / Stout St	• One valve (Wainui Rd) had to be opened. • Rainfall was not significant at any site.
7-Sep-2018	1.0	3 days	Stout St	• One valve (Wainui Rd) had to be opened.

Date	Highest ARI (years)	Duration	Site	Comments/notes
				• Rainfall was not significant at any site. (Gisborne Airport rain gauge blocked.)
13-Jun-2019	89.3	30 min	Wheatstone Rd	• Two valves had to be opened (Wainui Rd and Seymour/Turenne). • Very intense, short duration rainfall event on 13-Jun-2019 from 17:30 to 18:30 (NZST); valves opened at Wainui Rd and Seymour/Turenne from 19:35. • High intensity rainfall recorded at Paraone Rd, Stout St and Waikanae Creek; rainfall not significant at Gisborne Airport Met Station and Stout Street. Localised event.
15-Oct-2019	2.8	6 hours	Stout St	• One valve had to be opened (Wainui Rd). • For the 6 hour duration, Gisborne Airport and Stout Street rain gauges had an ARI of more than 2 years. All other durations (and sites) had an ARI of less than 2 years. • The heavier rain was in the west of the city (not the east, where the valve was opened).

The valves were opened on seven occasions when the ARIs were less than 2 years at all sites and for all durations (12-May-2017; 29-May-2017; 3-Sep-2017; 11-Jun-2018; 6-Aug-2018; and 7-Sep-2018). On another occasion (15-Oct-2019) the ARIs were greater than 2 years at sites in the west of the city (but the only valve which was opened was in the east).

Some of the events listed above could have been so localised that they were not captured by the city rain gauges. This would require further analysis to examine the location of the opened valves in comparison to the rain gauge sites.

The valves were opened on eight occasions when rainfall had an ARI of more than two years at one site at least. Where the rainfall had an ARI of more than 2 years these were associated with:

- Localised, short duration, high intensity rainfall events (13-Jun-2019). The high rainfall intensities make this event stand out from all the other events; the highest ARI was 89 years (at Wheatstone Rd for the 30 min duration).
- Short and medium durations (up to 12 hours): 13-Apr-2017.
- Medium and long durations (6 hours to 1 day): 4-Apr-2017.
- All durations (short, medium and long): 18-Apr-2014; 11-Jun-2014.
- Different durations at different sites (no clear pattern to rainfall events) on 4-Aug-2014; 20-Sep-2015; and 4-Jun-2018.

Apart from the event on 13-Jun-2019, when it was clearly the high intensity, short duration rainfall which led to the scours being opened, further analysis is needed to try to establish the type of event which is likely to lead to the scours being opened (e.g. short, medium or long duration). This would need further assessment of the timing of the rainfall in relation to the time the scours were opened, and the time required for runoff to reach the wastewater network. Again, the location of the opened valves in comparison to the rain gauge sites is crucial to assess how localised the events are.

Historical rainfall at Paraone Rd rain gauge

The rainfall from 2014 to 2019 has been examined at Paraone Rd rain gauge for different intervals (1-hour, 6-hour, 12-hour, 24-hour, 48-hour and 72-hour). The maximum rainfall for each interval might be less than the absolute recorded, e.g. the 1-hour interval is recorded on the hour. The figures are reproduced in Annex C (also included for reference are figures for Stout St rain gauge). The 1.58 year and 2 year ARIs were included on each figure, as well as the scour events.

Table 2 below shows the maximum rainfall recorded at Paraone Rd rain gauge over each rainfall event (for different intervals) when the scours were opened. The squares shaded in grey highlight when the maximum rainfall for that event and interval exceeded the 1.58 year ARI.

Table 2: Maximum Rainfall at Paraone Rd by Event and for Different Intervals

No.	Date scours opened	Maximum rainfall (mm) recorded over rainfall event & interval					
		1-hour	6-hour	12-hour	24-hour	48-hour	72-hour
1	18-Apr-2014	24.5	59.5	104.5	112.5	138.5	138.5
2	11-Jun-2014	16.0	41.0	67.5	95.0	110.5	110.5
3	4-Aug-2014	8.0	33.5	63.5	109.0	114.0	114.0
4	20-Sep-2015	14.4	38.6	59.2	73.0	74.8	140.2
5	4-Apr-2017	15.4	33.0	48.2	79.0	79.0	92.0
6	13-Apr-2017	11.0	36.2	47.2	55.4	55.4	56.2
7	12-May-2017	9.4	23.2	30.8	60.0	60.0	63.8
8	29-May-2017	12.8	25.6	39.8	40.4	52.4	62.2
9	3-Sep-2017	8.6	17.0	26.8	33.0	60.2	42.8
10	4-Jun-2018	20.6	46.6	67.2	82.4	94.2	98.4
11	11-Jun-2018	5.0	16.8	22.6	29.8	48.6	29.8
12	6-Aug-2018	4.4	13.4	19.8	29.4	49.2	46.0
13	7-Sep-2018	2.8	11.6	18.6	23.0	37.0	34.2
14	13-Jun-2019	22.0	31.4	53.8	59.6	77.6	69.0
15	15-Oct-2019	8.0	26.8	36.4	58.0	60.4	72.8
Average		**12.2**	**30.3**	**47.1**	**62.6**	**74.1**	**78.0**
HIRDS rainfall (1.58 year ARI)		**16.1**	**42.5**	**58.5**	**77.4**	**98.4**	**111.0**
HIRDS rainfall (2 year ARI)		**18.0**	**47.2**	**64.7**	**85.5**	**108.0**	**122.0**

The table shows that, in general, the maximum rainfall at Paraone Rd during each scour discharge event does not exceed the 1.58 year ARI. The table also highlights the large variation in maximum rainfall depths between events.

The limitation of this approach is that it considers the maximum rainfall over the entire event, rather than up to when the scours are opened. There are occasions when the maximum rainfall occurs after the first scour has been opened.

Also examined was whether there was a link between rainfall depth (as opposed to the ARI) for different intervals and when the scours had to be opened.

A rainfall depth was selected which was exceeded during at least eight scour events (i.e. the majority of events). The number of times this depth was exceeded in “non-scour” events was also examined. The rainfall event associated with each scour event was considered separately from “non-scour events”. This has its limitations; the rainfall might have fallen several hours before or after the scours were opened and there might not therefore be any direct link between the two.

Table 3 below summarises the results for Paraone Rd rain gauge.

Table 3: Paraone Rd Rain Gauge – Rainfall Depth and Overflow Events

Interval	Selected rainfall depth (mm)	No. of scour events where rainfall greater than selected rainfall depth	No. of times rainfall depth was exceeded when scours were not opened
1 hour	10 mm	8	31
6 hours	31 mm	8	5
12 hours	47 mm	8	3
24 hours	59 mm	8	4
48 hours	60 mm	10	6
72 hours	68 mm	8	5

The 1-hour rainfall was greater than 10 mm during eight rain events when the scours were opened. However, there were a further 31 occasions when the hourly rainfall was more than 10 mm when the scours were not opened. This suggests that there is not a strong link between rainfall lasting a short interval and the scours being opened.

With the longer intervals (6 hours, 12 hours, 24 hours, 48 hours, 72 hours), the number of times the selected rainfall depth was exceeded is greater during scour events than non-scour events. However, given the limitations and uncertainties, it is not possible to say that there is a definite link between rainfall with a longer duration and the scours being opened.

Even though the depth of rainfall was exceeded in the majority of cases (i.e. at least eight times) during scour events, this still leaves up to seven events where the rainfall was less than the selected depth. As mentioned above, the rainfall for any specific interval might not be the direct cause of the scours being opened – it may also depend on where and when the rain occurred and the travel time. The scours being opened could also be a result of other factors, e.g. a blockage in the system.

Pattern to rainfall events when scours are opened

The figures in Annex D show the hourly rainfall at Paraone Rd prior to when the scours were opened for each event.

It is sometimes difficult to define the start of the rainfall event. In some cases, what has been classed as one event might actually be two events which have no impact on each other and which are completely separate in terms of the runoff they generate. In other cases, a seemingly separate rainfall event which has not been considered could actually have a significant impact on antecedent conditions and runoff rates.

There appears to be an issue with the event on 11/06/2018; two figures are provided – Figure 11/06/2018 (A) shows the rainfall prior to when the scours were opened and Figure 11/06/2018 (B) provides the rainfall for the whole rain event. It seems unlikely that the scours had to be opened for so little rainfall (11/06/2018 (A)), unless they were opened as a preventative measure. For this reason, this event has not been included in this analysis.

In general, the rainfall at Paraone Rd lasted for a minimum of 17 hours before the scours were opened (10 events). There tends to be either no gap in the rainfall event or one that lasts for no more than an hour (11 events). In most events (nine), the maximum hourly rainfall exceeds 9 mm. However, these aspects have all been considered separately; only six events have all three attributes.

This analysis is limited as it only examines the rainfall data from one site. In addition, it is purely a retrospective analysis; it does not appear possible to predict when scours will be opened, based on the assessment of rainfall.

Relationship between overflows and shallow groundwater levels

Elevated shallow groundwater levels may be a source of water ingress into the pipes. As a result of this, groundwater levels have been examined.

GDC has monitoring bores at Cameron Rd, in the north-west of Gisborne (see map in Annex A). Cameron Road No1 Bore (GPB099) is in the Te Hapara Sands, a shallow aquifer which covers a large area of the city. Groundwater levels at Cameron Road No1 Bore are presented in Annex E.

The groundwater levels at the monitoring point may not be representative of groundwater levels where the pipe network is. In addition, a high groundwater level does not necessarily mean that groundwater is entering the pipe network.

The figure in Annex E shows that most overflows occur at elevated groundwater levels or where groundwater levels are increasing (rather than decreasing), i.e. when the shallow aquifer is recharging rather than declining. Rainfall is seasonal and as the autumn and winter progress, there is more rainfall and aquifers are recharging.

Part 2: Examination of rainfall events when scours remained closed

The graphs for each event are provided in Annex F and show the ARIs for different durations at each site. Each graph has a red dotted line showing the 2 year ARI. A rain event could last for 3 days; the ARI for each duration is the ARI associated with the maximum rainfall recorded over that duration (whether that is 10 minutes, 6 hours or 2 days) within that three day period.

The rain gauge at Gisborne Airport was blocked during the rain event on 29-30 December 2018 and the rain gauge at Wheatstone Rd appears to have been blocked during the 28-Jan-2016 event.

The graphs show that three of the six events examined had ARIs of greater than 2 years at one site at least:

- The event on 4-Nov-2015 appears to have been relatively localised, with only Wheatstone Rd recording significant rainfall (with an ARI of 26 years for the rainfall of 1 day duration) – the localised nature of this event could explain why the scours did not have to be opened;
- On 28-Jan-2016 both rain gauges at Paraone Rd and Stout Street recorded rainfall with an ARI of greater than 2 years for the medium (1 hour) to long durations (1 day) (Wheatstone Rd rain gauge was blocked); and
- On 16-Feb-2017, Paraone Rd, Wheatstone Rd and Stout St all recorded rainfall with an ARI of greater than 2 years for at least one duration.

Every rainfall event is different and it is very difficult to establish why the scours have to be opened in one event and not another.

Further assessment could be undertaken of the timing of the rainfall in relation to the time the scours were opened, and the time required for runoff to reach the wastewater network. The location of the opened valves in comparison to the rain gauge sites is crucial to assess how localised the events are.

Summary and Conclusions

A high level analysis of rainfall and scour events was undertaken to establish if there is a correlation between rainfall intensity/duration and when the wastewater network scour valves have to be opened in Gisborne city. The analysis comprised examination of 15 scour discharges between April 2014 and February 2020 and seven high rainfall events where the scours were not opened.

Rainfall data were obtained from GDC's rain gauge network located across the city. Rainfall depths for different durations (10 minutes through to 3 days) and different return periods (1.58 years through to 250 years) were determined using NIWA's web-based programme (HIRDS).

The analysis indicates that each rainfall event is different and there is no clear relationship between rainfall duration/depth and the point at which the scour valves are required to be opened. However, the following observations are made:

1. The scour valves were opened on eight occasions where the rainfall had an ARI of more than two years. However, the duration of the rainfall that exceeded the 2 year ARI event was variable and included:
    a. Localised, short duration, high intensity rainfall events (13-Jun-2019). The high rainfall intensities make this event stand out from all the other events.
    b. Short and medium durations (up to 12 hours): 13-Apr-2017.

c. Medium and long durations (6 hours to 1 day): 4-Apr-2017.
d. All durations (short, medium and long): 18-Apr-2014; 11-Jun-2014.
e. Different durations at different sites (no clear pattern to rainfall events) on 4-Aug-2014; 20-Sep-2015; and 4-Jun-2018.

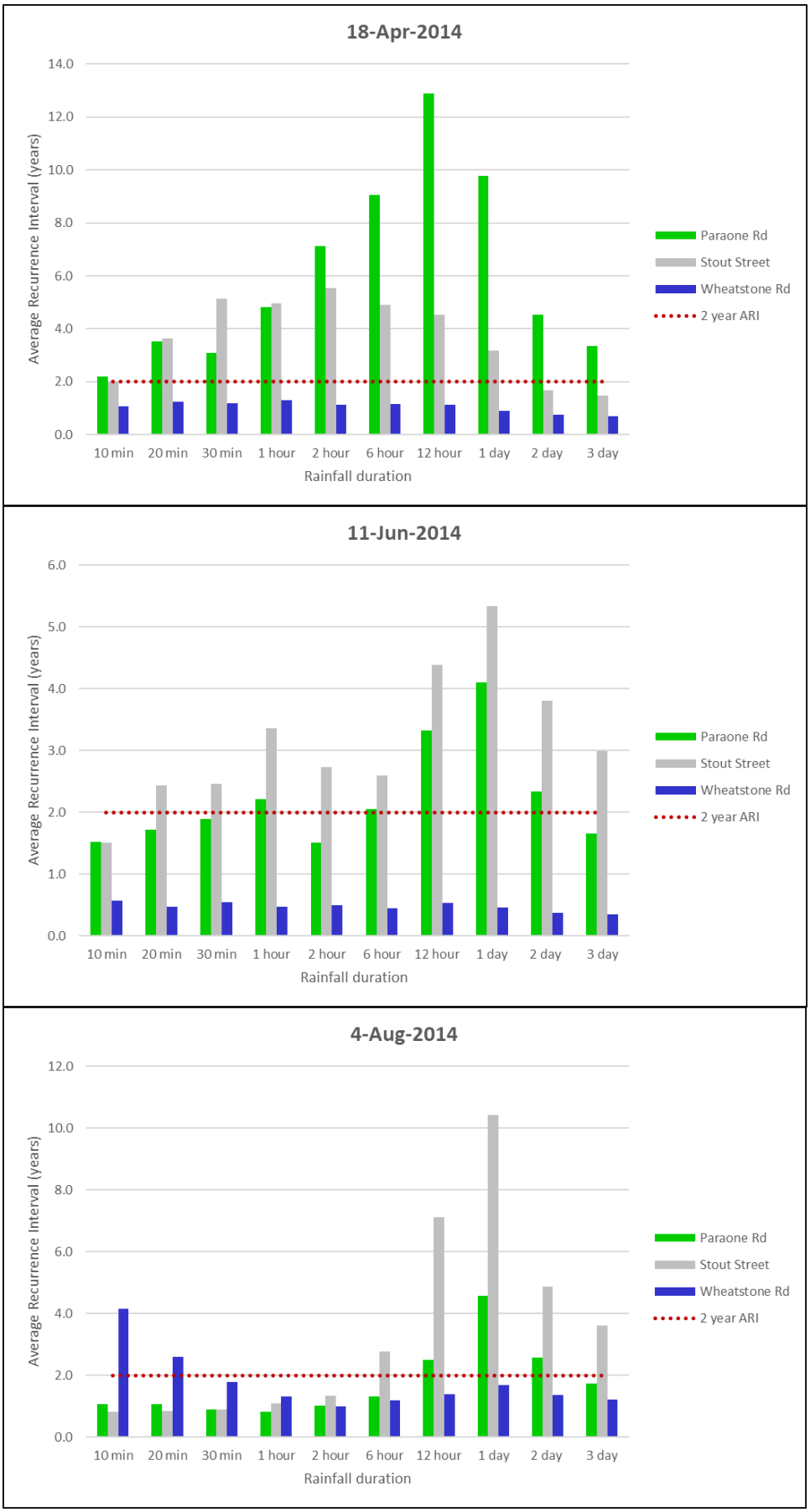
2. There is therefore no clear indication of the 'critical' rainfall event that leads to the scour valves being opened. Both short duration/high intensity and long duration/lower intensity events can give rise to overflows.
3. There were also eight occasions where the scour valves were opened for rainfall events when the ARI was less than 1.58 years – indicating that the current network overflow performance is lower th1n the 1.58 year ARI rainfall event. However, HIRDS is not designed for sub-annual return periods and hence it has not been possible to determine the smallest return period event that has resulted in the scour valves being opened.
4. Rainfall depth for any specific interval might not be the direct cause of the scours being opened – it may also depend on when and where the rain occurred and the travel time within the network.
5. Based on the Paraone Rd rain gauge, rainfall lasts for 17 hours (in general) before the scour valves are opened. There tends to be either no gap in the rainfall event or one that lasts for no more than an hour. In most events the maximum hourly rainfall exceeds 9 mm.
6. Elevated shallow groundwater levels may be a source of water ingress into the pipes. When groundwater levels are examined in the north-west of the city, it shows that most overflows occur when the shallow aquifer is recharging rather than declining. Rainfall is seasonal and as the autumn and winter progress, there is more rainfall and the shallow aquifers are recharging.
7. There have been instances where rainfall has exceeded the 2 year ARI event, but the scours have not been opened.

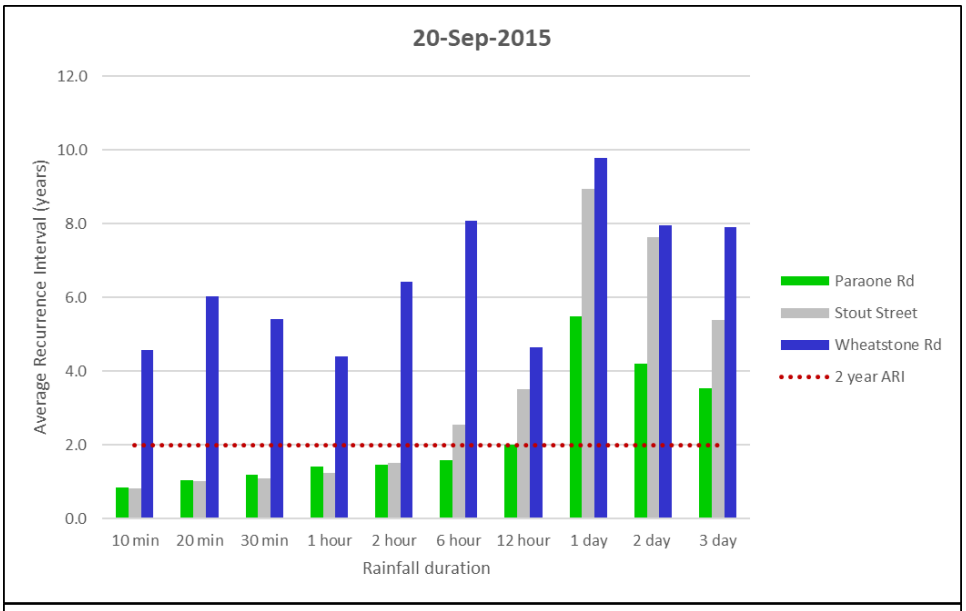
References

NIWA. 2017. HIRDS (High Intensity Rainfall Design System) (version 4). Available at: https://hirds.niwa.co.nz/

Annex A: Location of the rain gauges used in the analysis

Annex B: Part 1: Rainfall events and ARIs




20-Sep-2015
12.0
10.0
8.0
6.0
4.0
2.0
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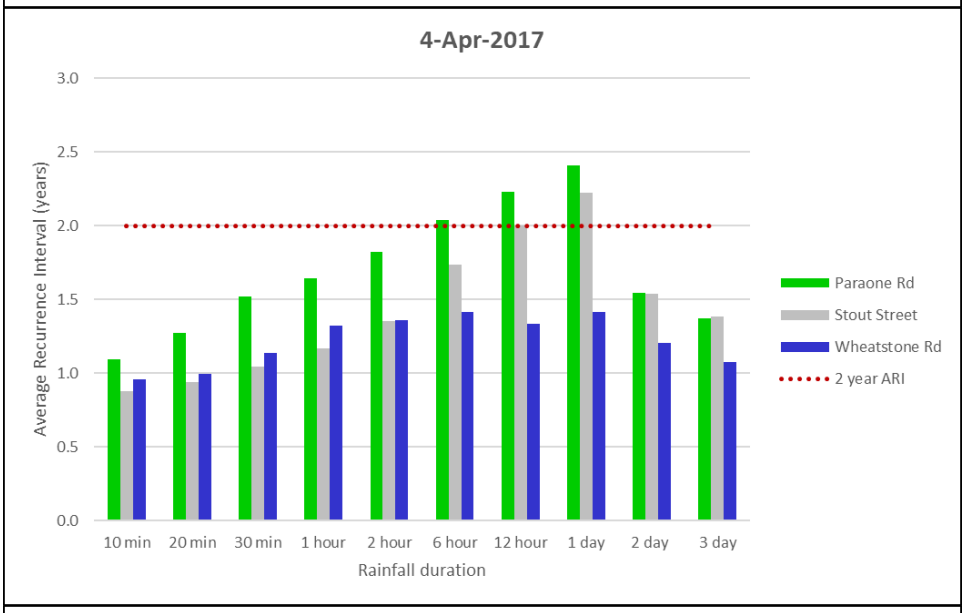
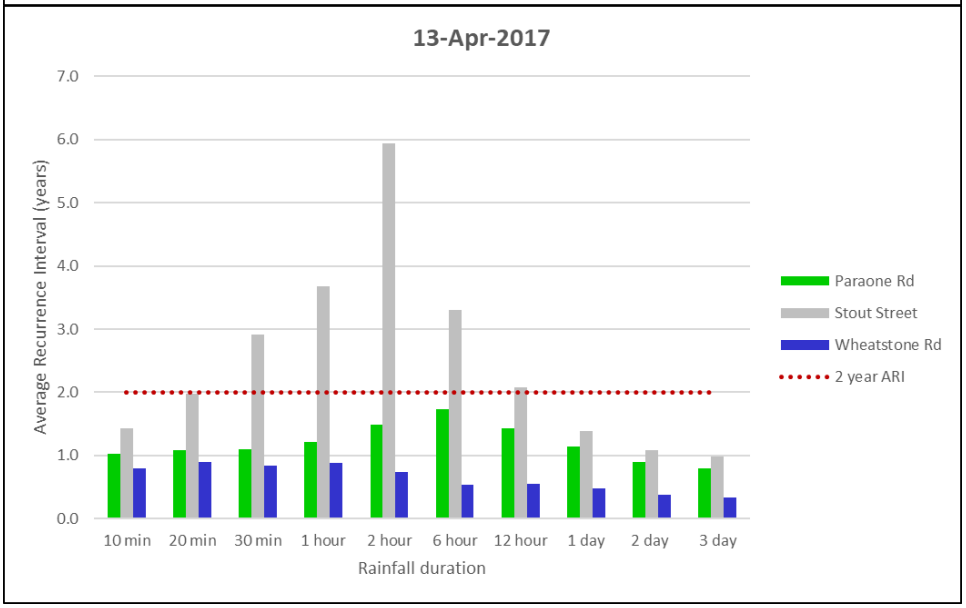
Average Recurrence Interval (years)
10 min
20 min
30 min
1 hour
2 hour
6 hour
12 hour
1 day
2 day
3 day
Rainfall duration
Paraone Rd
Stout Street
Wheatstone Rd
2 year ARI


4-Apr-2017
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Average Recurrence Interval (years)
10 min
20 min
30 min
1 hour
2 hour
6 hour
12 hour
1 day
2 day
3 day
Rainfall duration
Paraone Rd
Stout Street
Wheatstone Rd
2 year ARI


13-Apr-2017
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Average Recurrence Interval (years)
10 min
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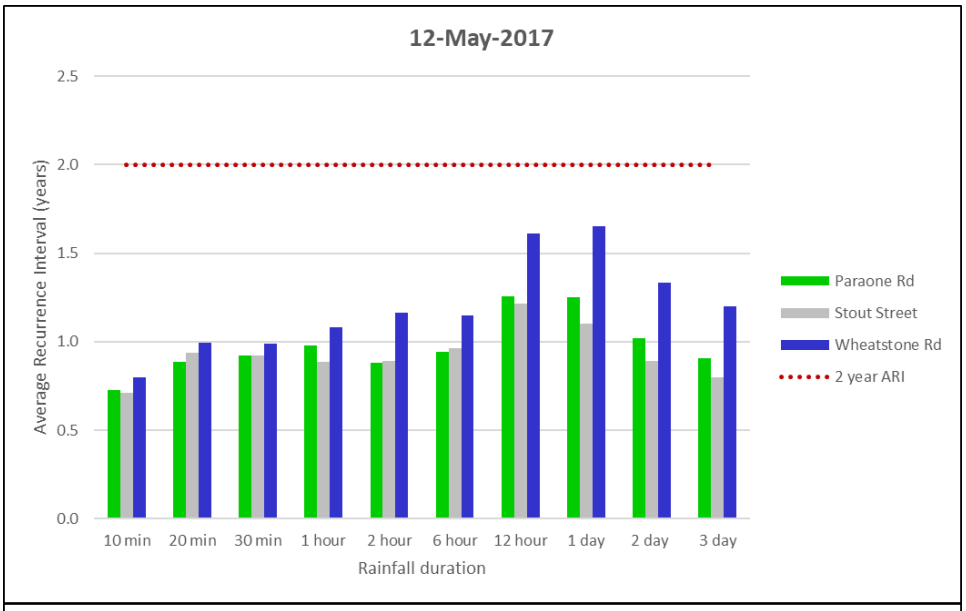
12 hour
1 day
2 day
3 day
Rainfall duration
Paraone Rd
Stout Street
Wheatstone Rd
2 year ARI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Average Recurrence Interval (years)
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2.0
1.5
1.0
0.5
0.0
10 min
20 min
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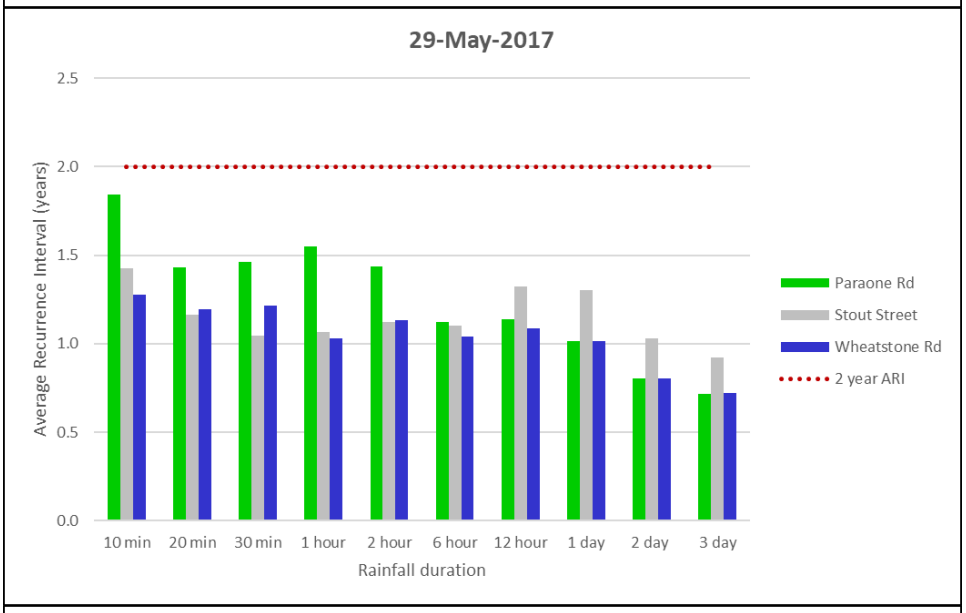
1 day
2 day
3 day
Rainfall duration
Paraone Rd
Stout Street
Wheatstone Rd
2 year ARI


29-May-2017
Average Recurrence Interval (years)
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1.5
1.0
0.5
0.0
10 min
20 min
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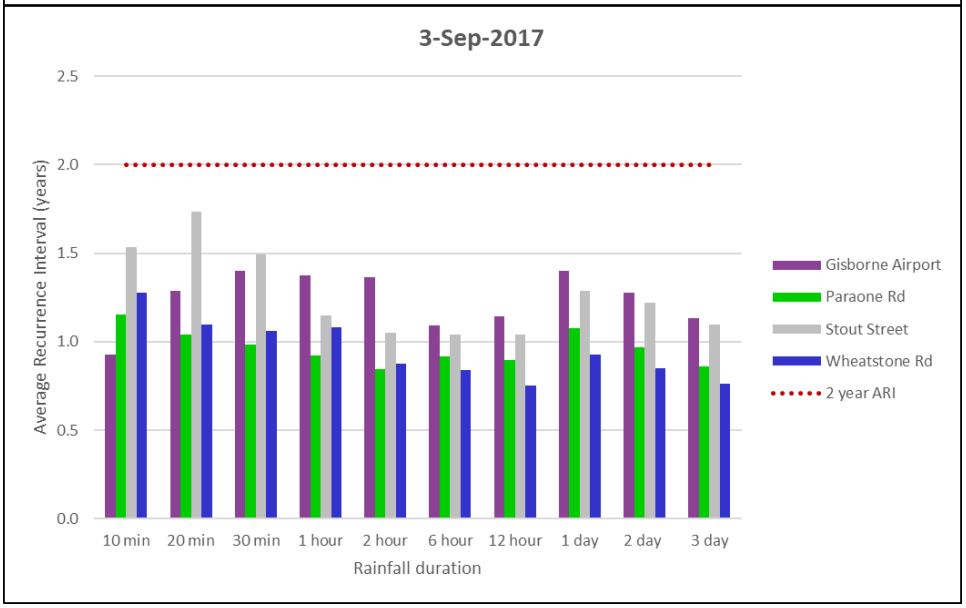
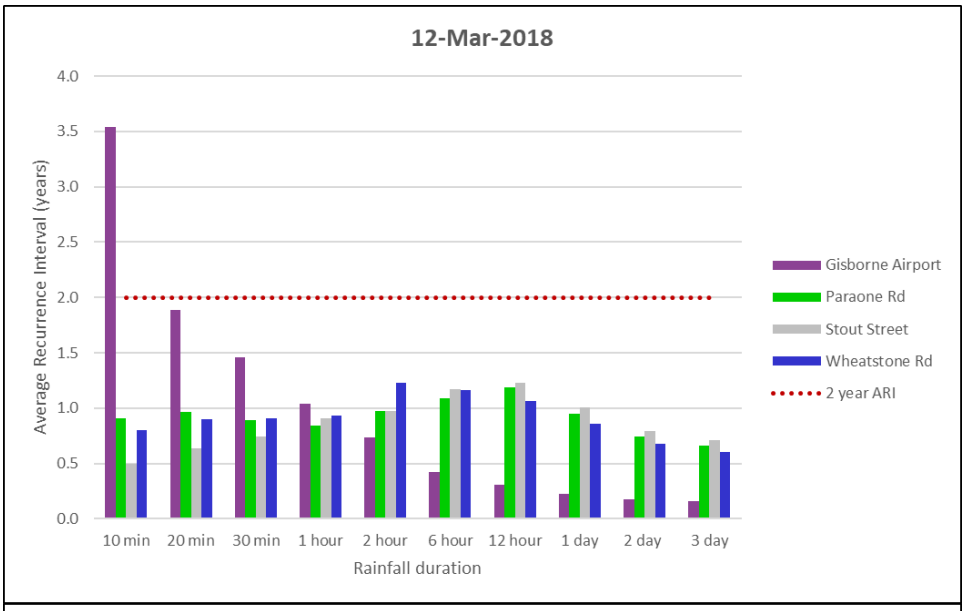
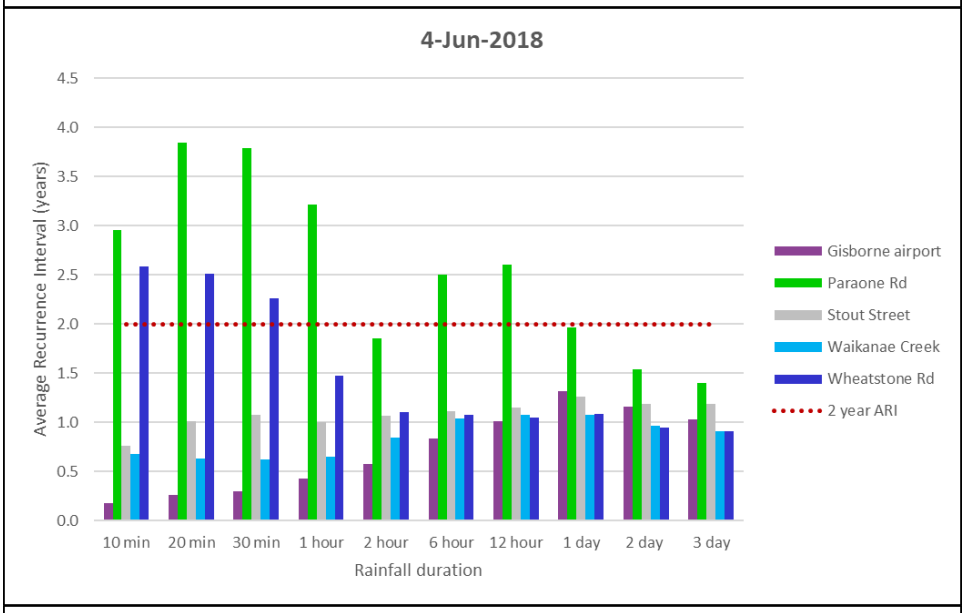
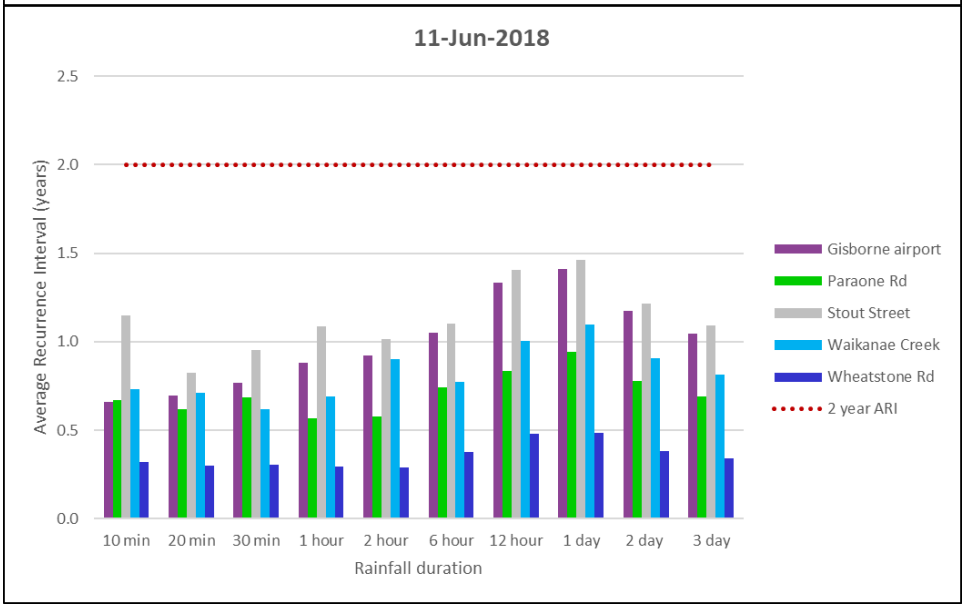
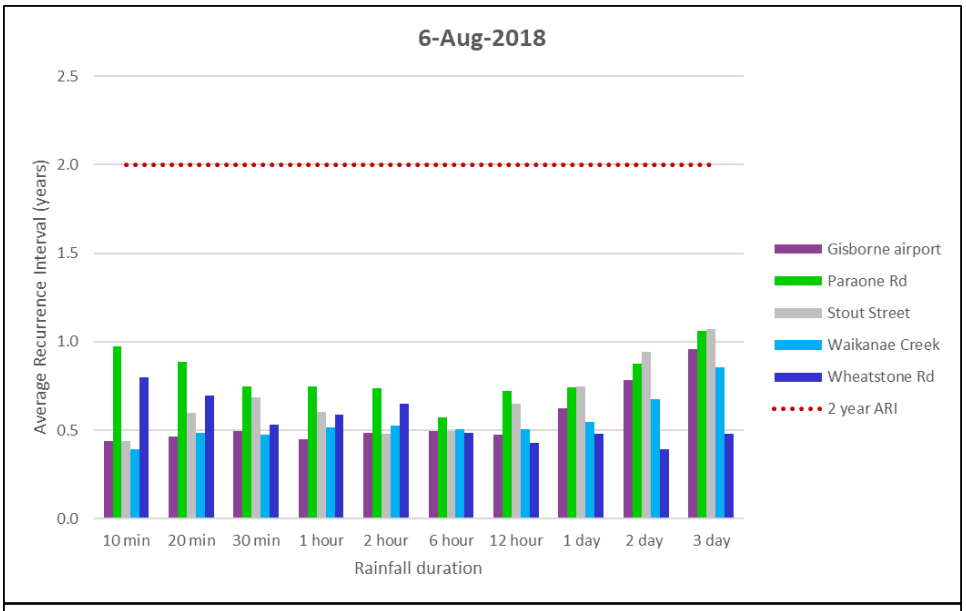
3 day
Rainfall duration
Paraone Rd
Stout Street
Wheatstone Rd
2 year ARI

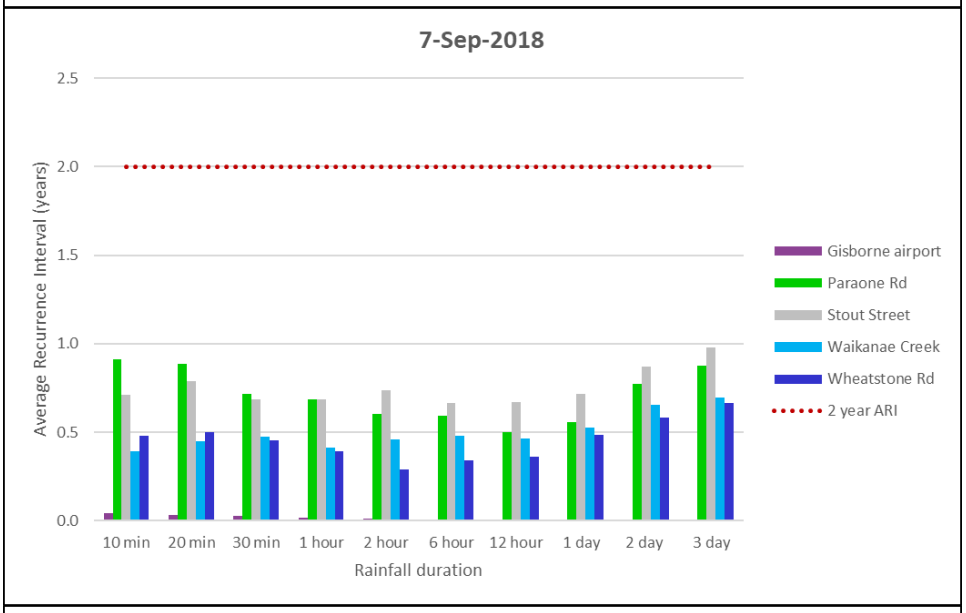

3-Sep-2017
Average Recurrence Interval (years)
2.5
2.0
1.5
1.0
0.5
0.0
10 min
20 min
30 min
1 hour
2 hour
6 hour
12 hour
1 day
2 day
3 day
Rainfall duration
Gisborne Airport
Paraone Rd
Stout Street
Wheatstone Rd
2 year ARI

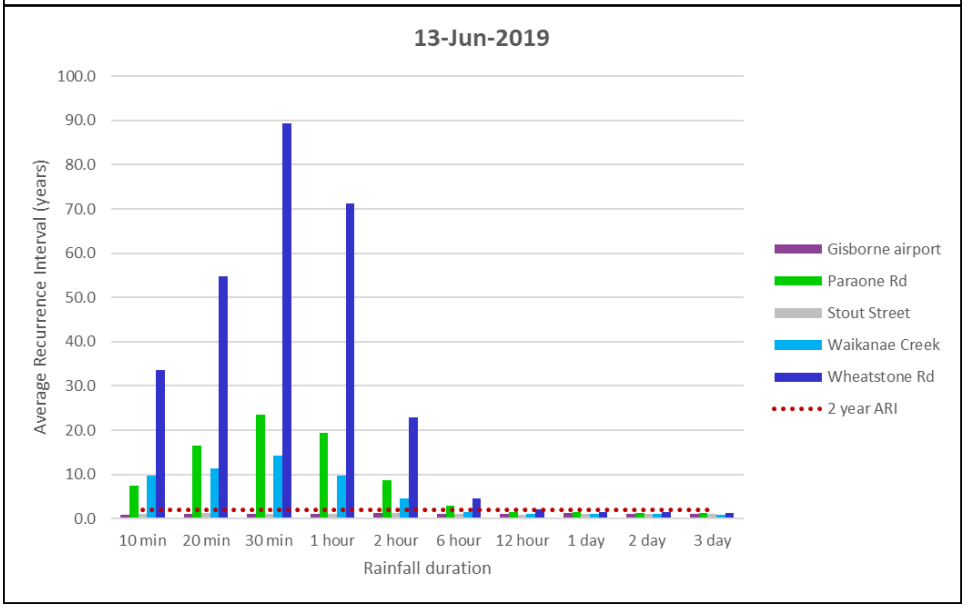

12-Mar-2018
Average Recurrence Interval (years)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10 min
20 min
30 min
1 hour
2 hour
6 hour
12 hour
1 day
2 day
3 day
Rainfall duration
Gisborne Airport
Paraone Rd
Stout Street
Wheatstone Rd
2 year ARI

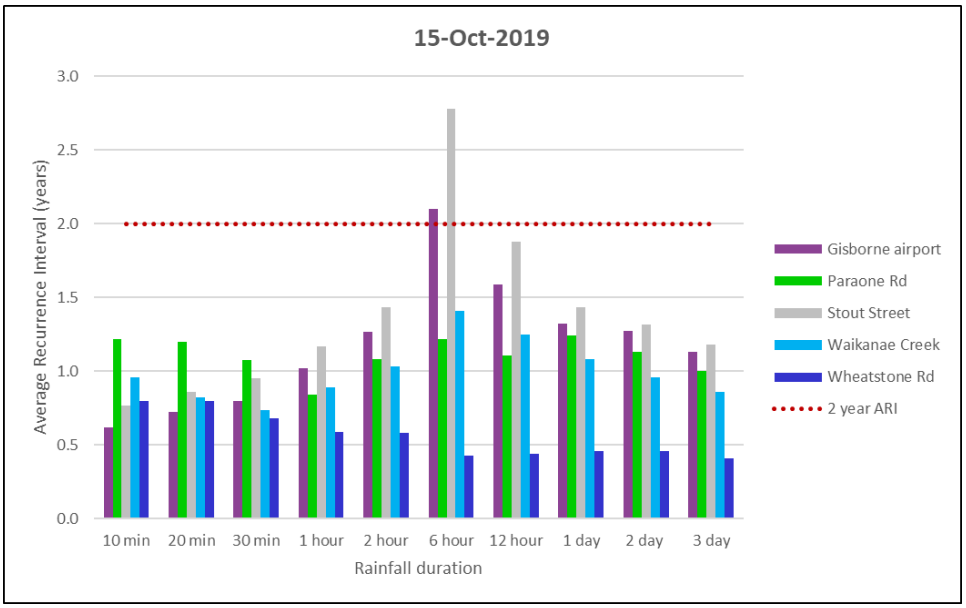

4-Jun-2018
Average Recurrence Interval (years)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10 min
20 min
30 min
1 hour
2 hour
6 hour
12 hour
1 day
2 day
3 day
Rainfall duration
Gisborne airport
Paraone Rd
Stout Street
Waikanae Creek
Wheatstone Rd
2 year ARI


11-Jun-2018
Average Recurrence Interval (years)
2.5
2.0
1.5
1.0
0.5
0.0
10 min
20 min
30 min
1 hour
2 hour
6 hour
12 hour
1 day
2 day
3 day
Rainfall duration
Gisborne airport
Paraone Rd
Stout Street
Waikanae Creek
Wheatstone Rd
2 year ARI

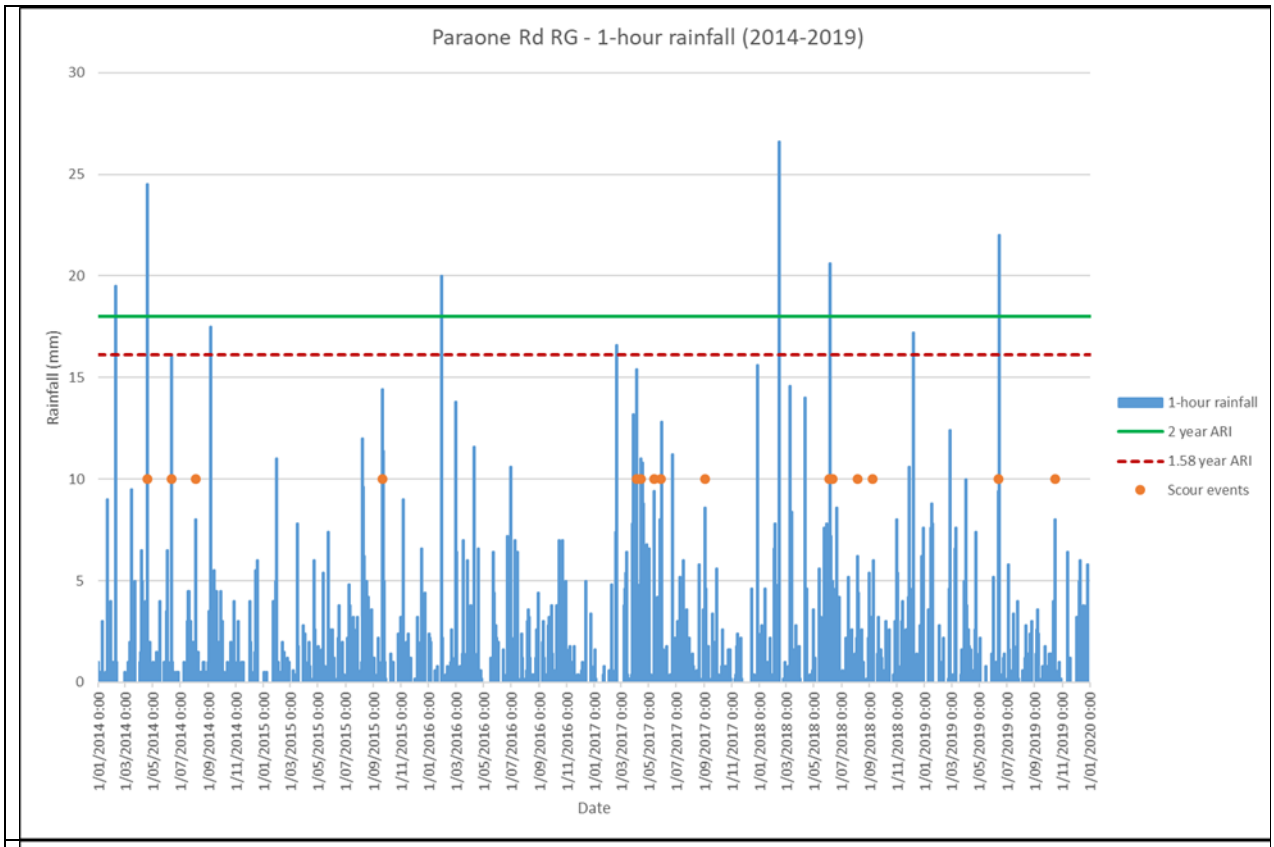

6-Aug-2018
Average Recurrence Interval (years)
2.5
2.0
1.5
1.0
0.5
0.0
10 min
20 min
30 min
1 hour
2 hour
6 hour
12 hour
1 day
2 day
3 day
Rainfall duration
Gisborne airport
Paraone Rd
Stout Street
Waikanae Creek
Wheatstone Rd
2 year ARI

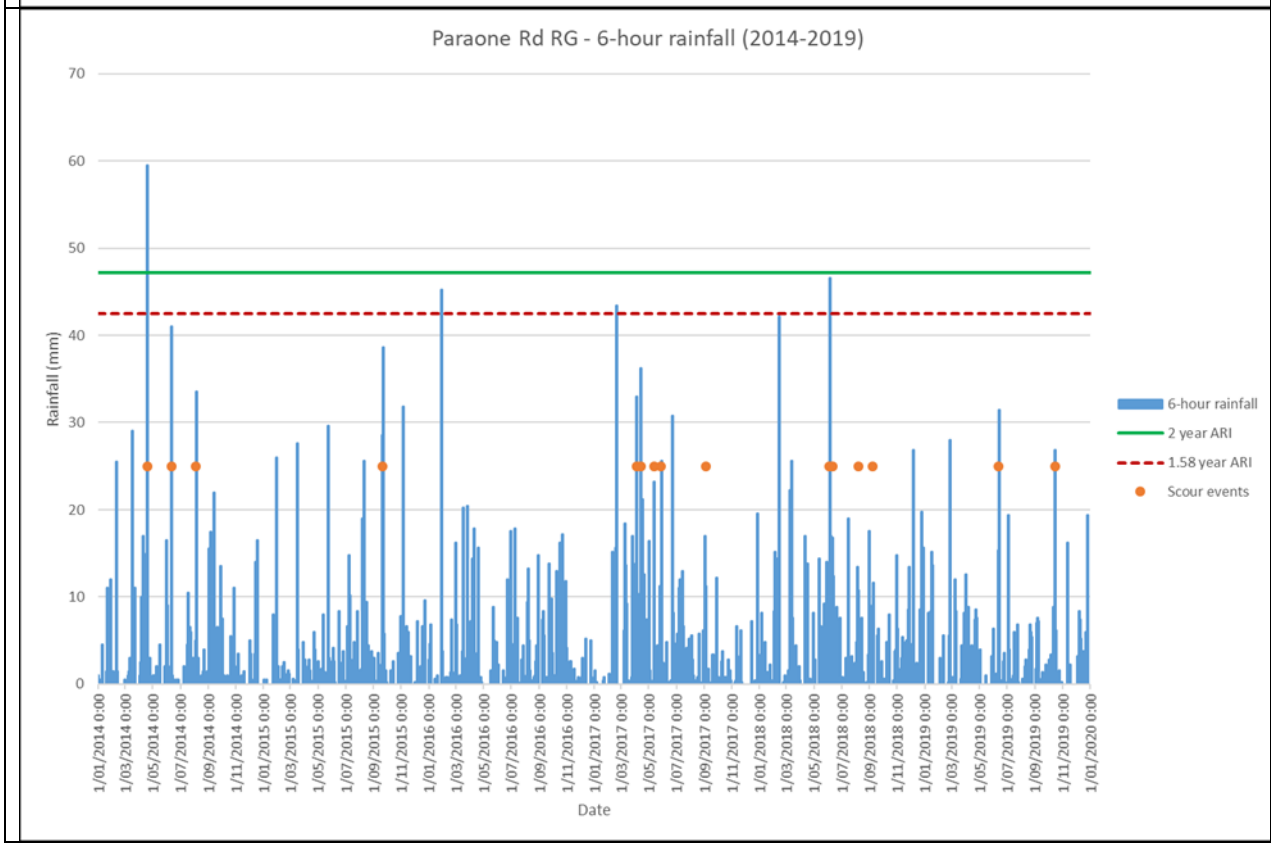

7-Sep-2018
Average Recurrence Interval (years)
2.5
2.0
1.5
1.0
0.5
0.0
10 min
20 min
30 min
1 hour
2 hour
6 hour
12 hour
1 day
2 day
3 day
Rainfall duration
Gisborne airport
Paraone Rd
Stout Street
Waikanae Creek
Wheatstone Rd
2 year ARI

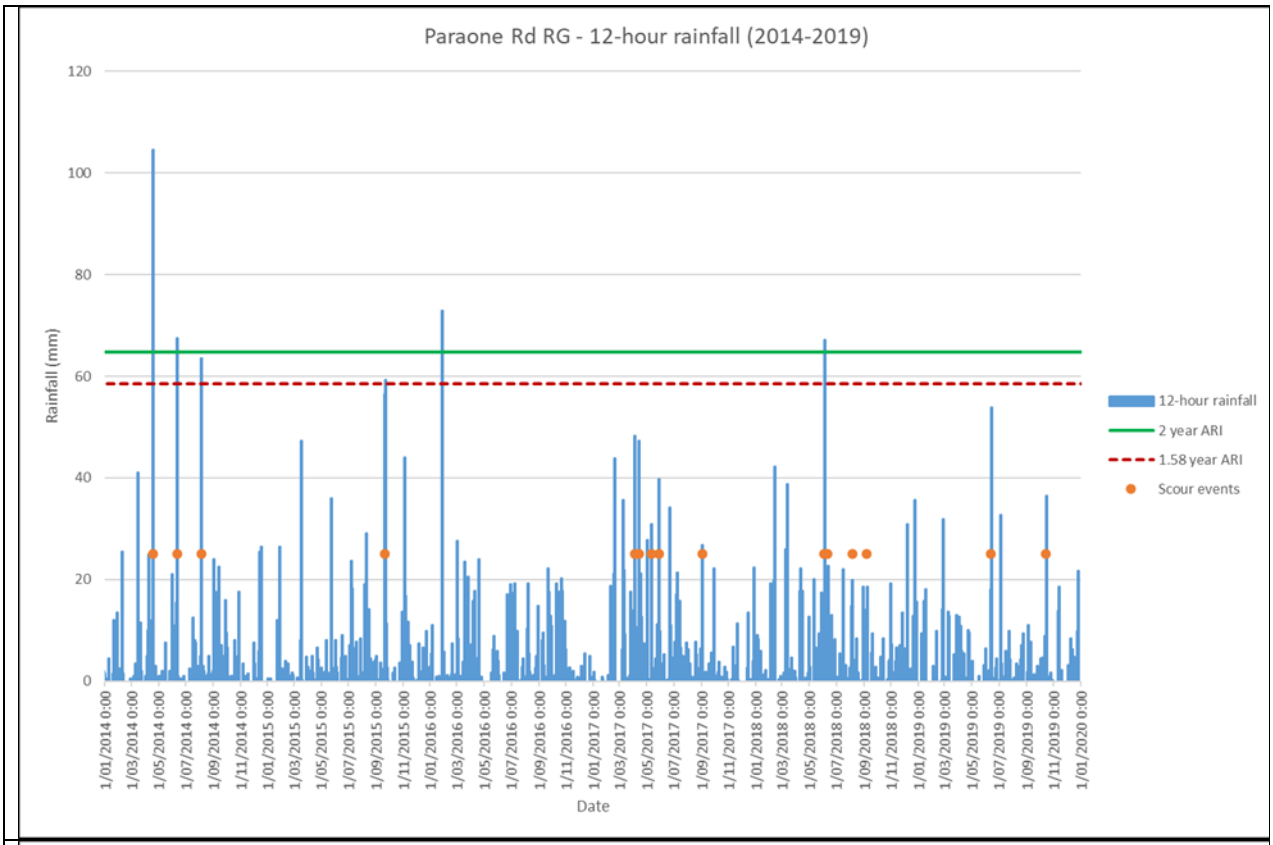

13-Jun-2019
Average Recurrence Interval (years)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
10 min
20 min
30 min
1 hour
2 hour
6 hour
12 hour
1 day
2 day
3 day
Rainfall duration
Gisborne airport
Paraone Rd
Stout Street
Waikanae Creek
Wheatstone Rd
2 year ARI

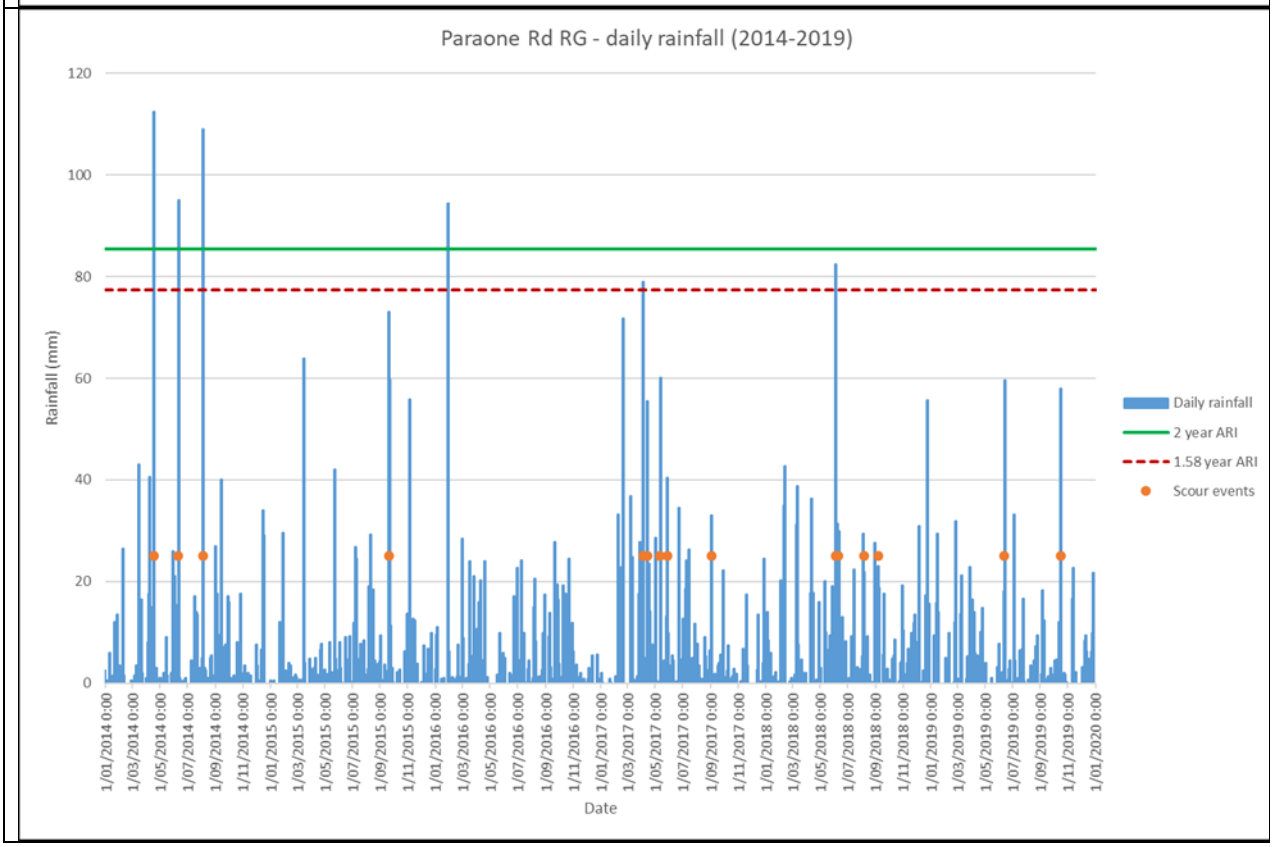

15-Oct-2019
Average Recurrence Interval (years)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10 min
20 min
30 min
1 hour
2 hour
6 hour
12 hour
1 day
2 day
3 day
Rainfall duration
Gisborne airport
Paraone Rd
Stout Street
Waikanae Creek
Wheatstone Rd
2 year ARI

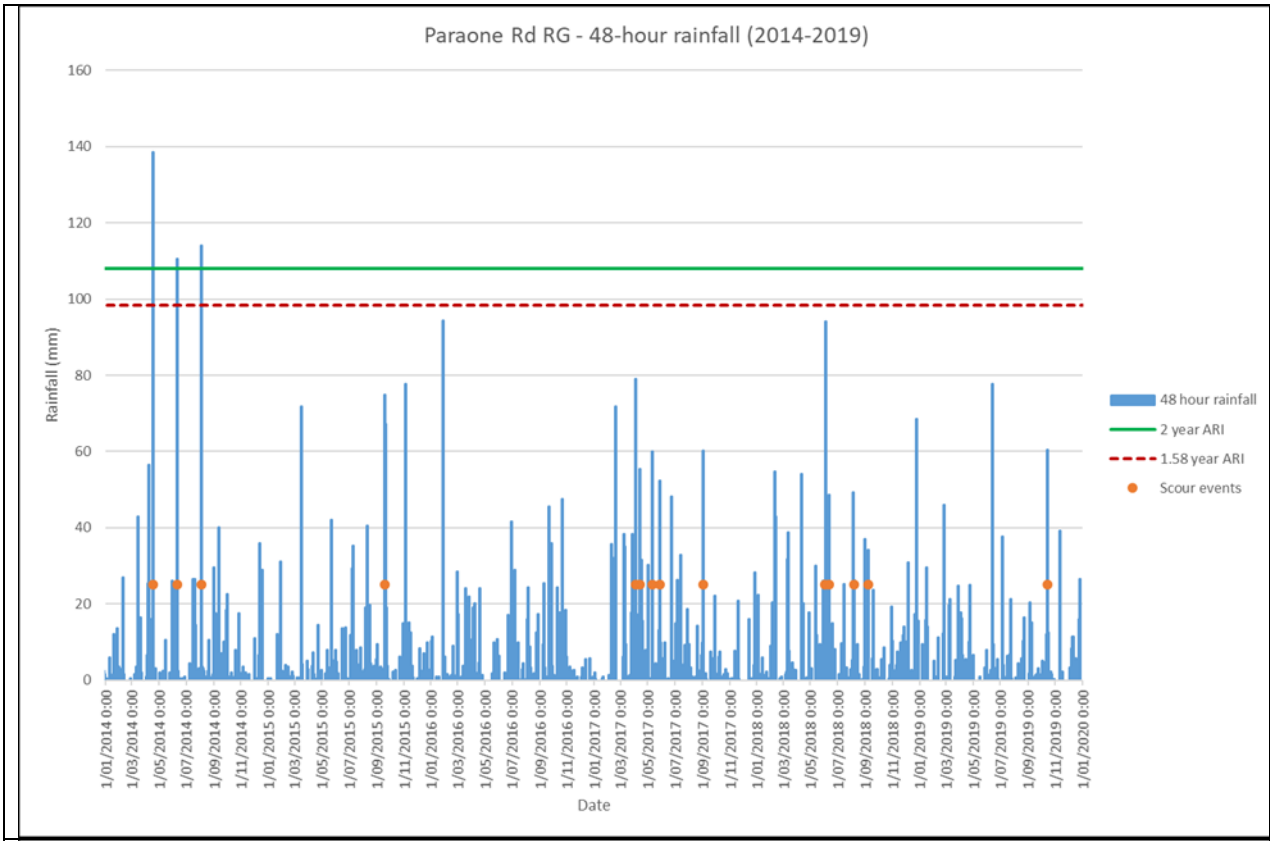
Annex C: Part 1: 1-hour, 6-hour, 12-hour, 24-hour, 48-hour and 72-hour rainfall at Paraone Rd and Stout St rain gauges

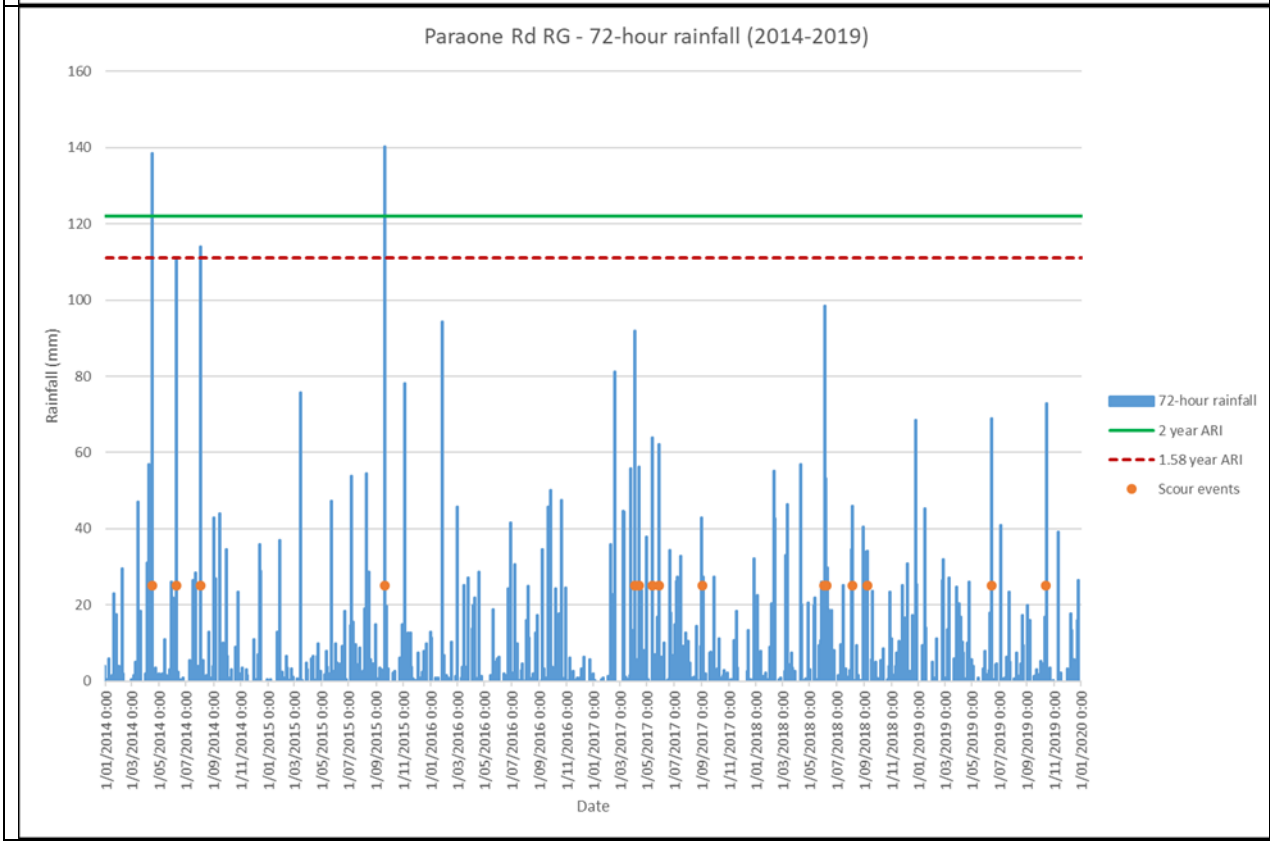


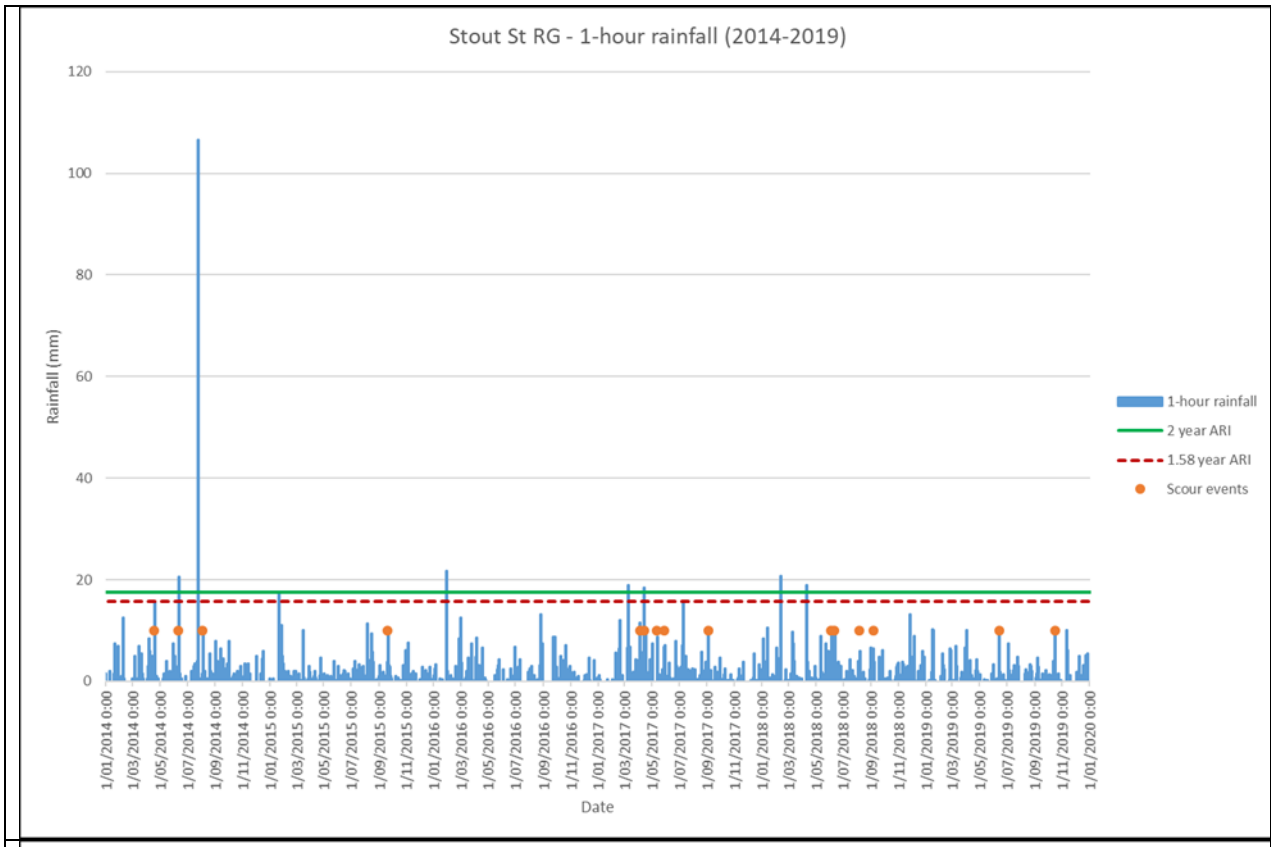


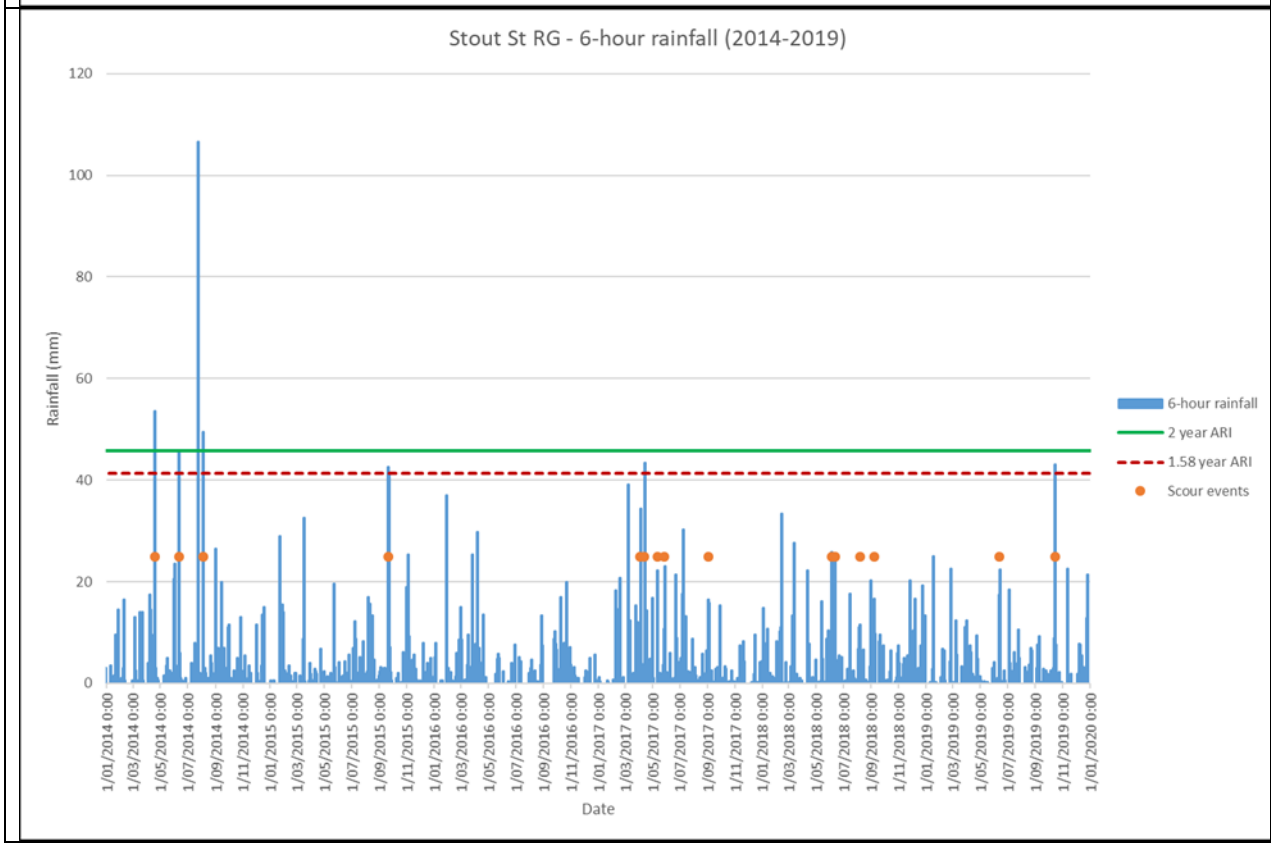

Paraone Rd RG - 12-hour rainfall (2014-2019)
Rainfall (mm)
Date
12-hour rainfall
2 year ARI
1.58 year ARI
Scour events

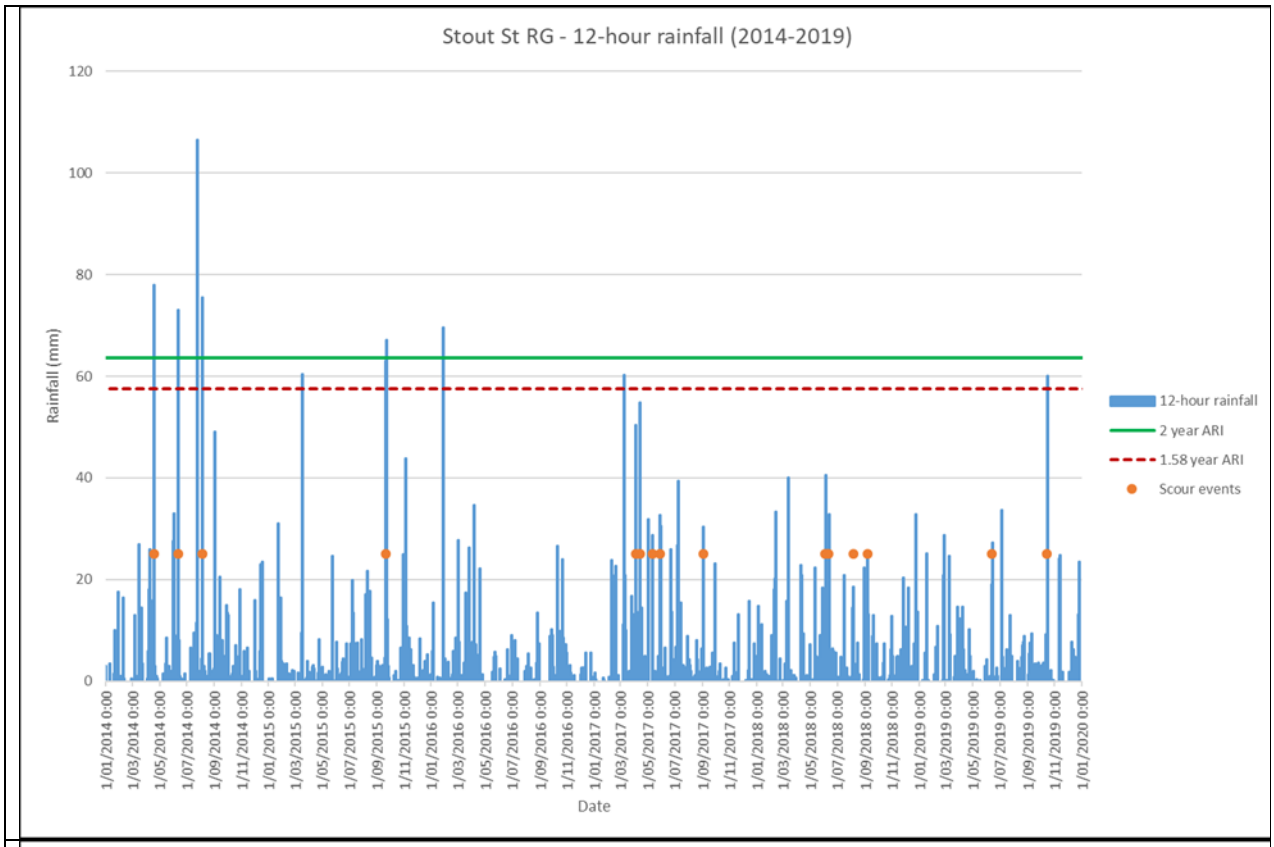

Paraone Rd RG - daily rainfall (2014-2019)
Rainfall (mm)
Date
Daily rainfall
2 year ARI
1.58 year ARI
Scour events

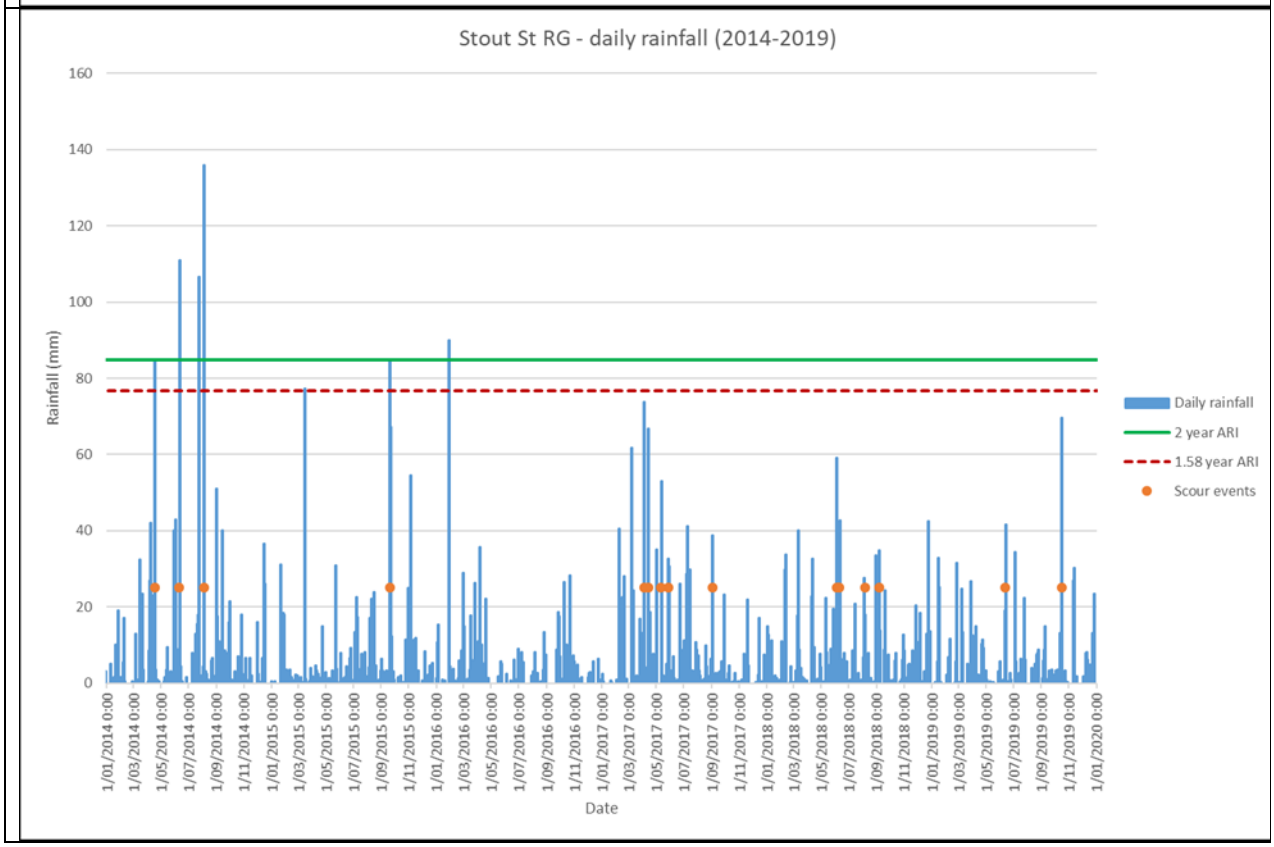

Paraone Rd RG - 48-hour rainfall (2014-2019)
Rainfall (mm)
Date
48 hour rainfall
2 year ARI
1.58 year ARI
Scour events

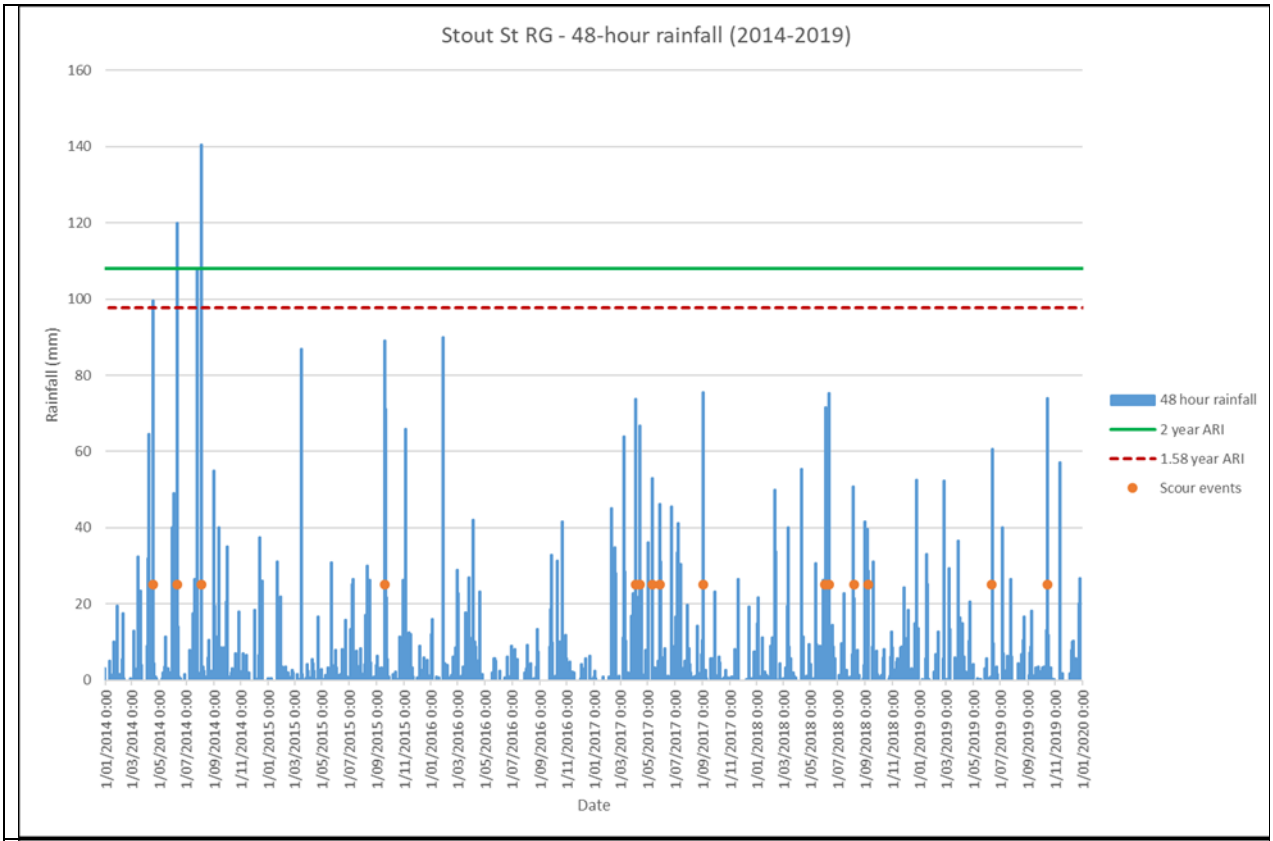

Paraone Rd RG - 72-hour rainfall (2014-2019)
Rainfall (mm)
Date
72-hour rainfall
2 year ARI
1.58 year ARI
Scour events

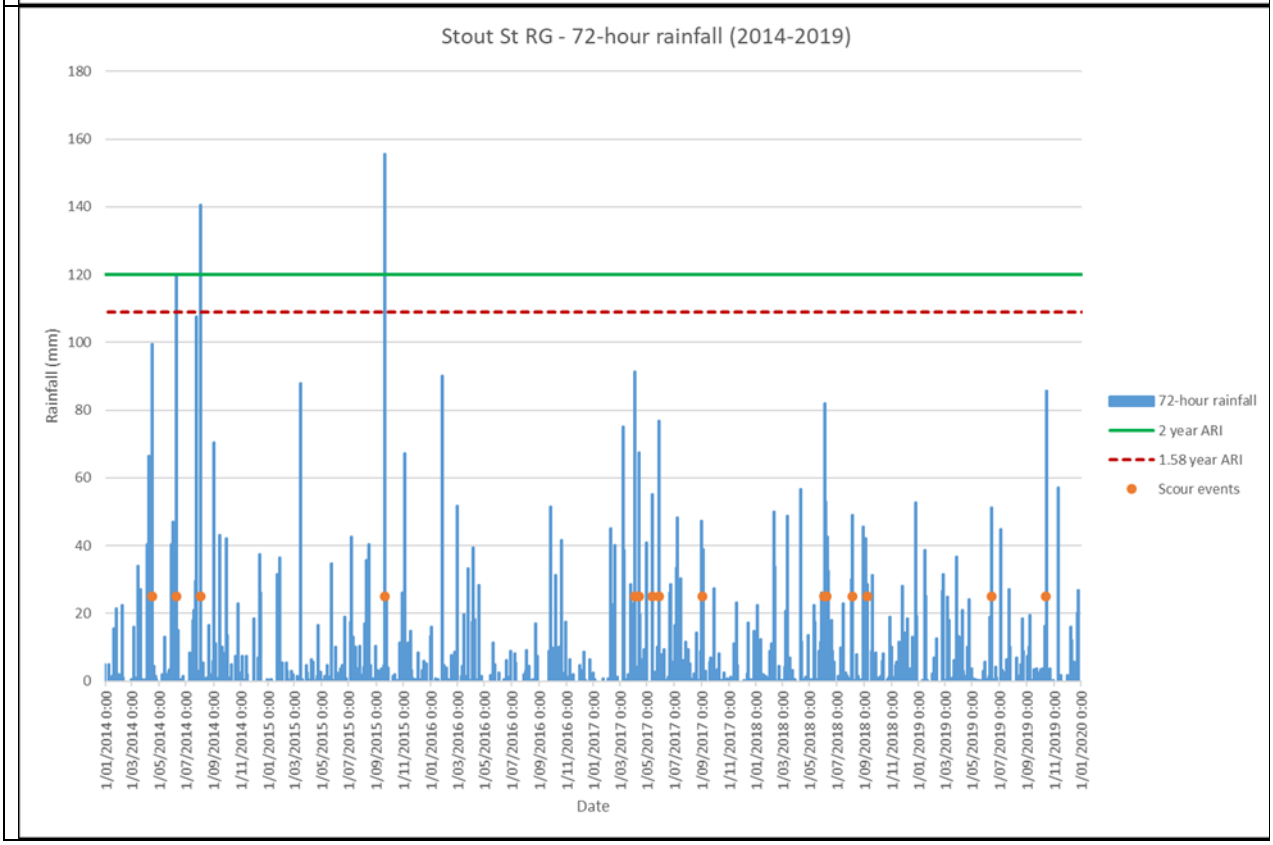

Stout St RG - 1-hour rainfall (2014-2019)
Rainfall (mm)
Date
1-hour rainfall
2 year ARI
1.58 year ARI
Scour events


Stout St RG - 6-hour rainfall (2014-2019)
Rainfall (mm)
Date
6-hour rainfall
2 year ARI
1.58 year ARI
Scour events

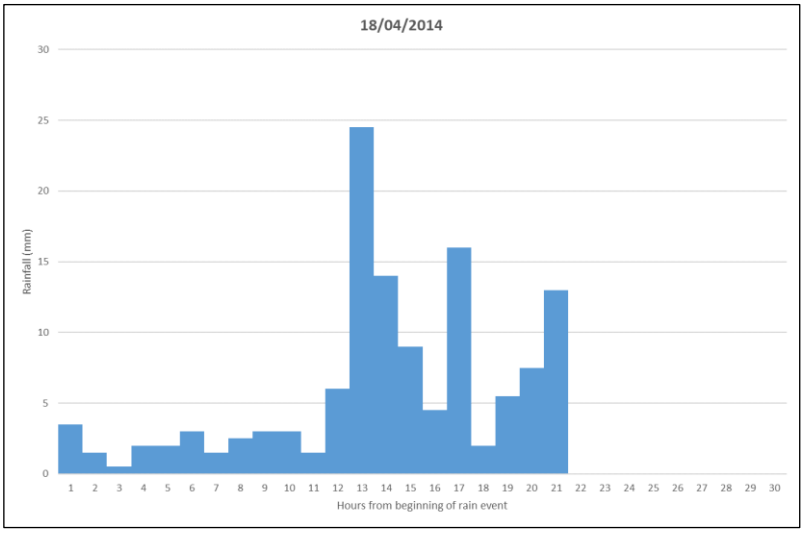

Stout St RG - 12-hour rainfall (2014-2019)
Rainfall (mm)
Date
12-hour rainfall
2 year ARI
1.58 year ARI
Scour events

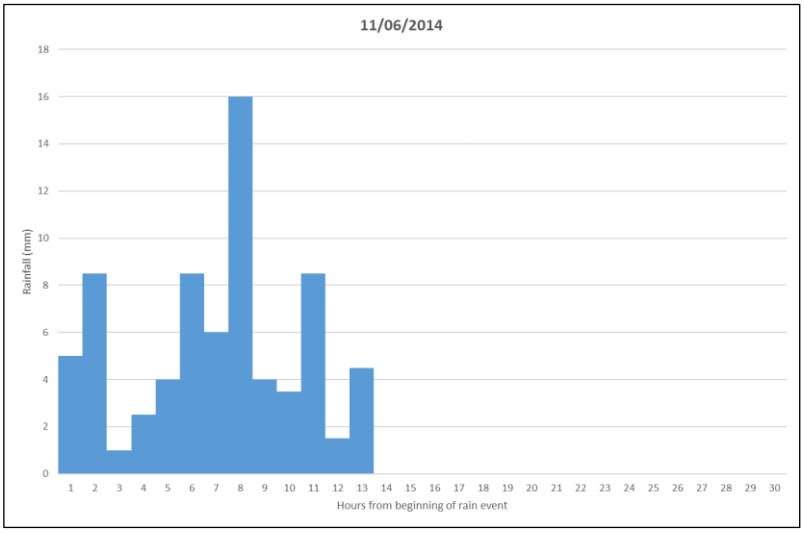

Stout St RG - daily rainfall (2014-2019)
Rainfall (mm)
Date
Daily rainfall
2 year ARI
1.58 year ARI
Scour events

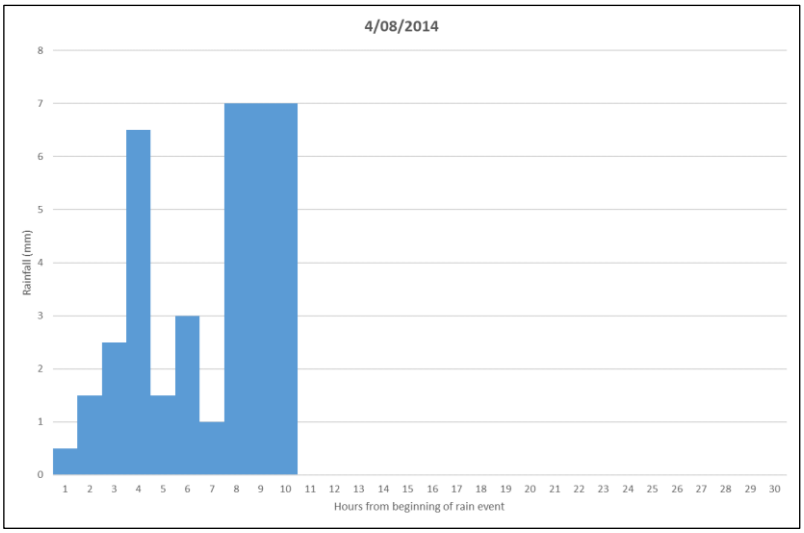

Stout St RG - 48-hour rainfall (2014-2019)
Rainfall (mm)
Date
48 hour rainfall
2 year ARI
1.58 year ARI
Scour events

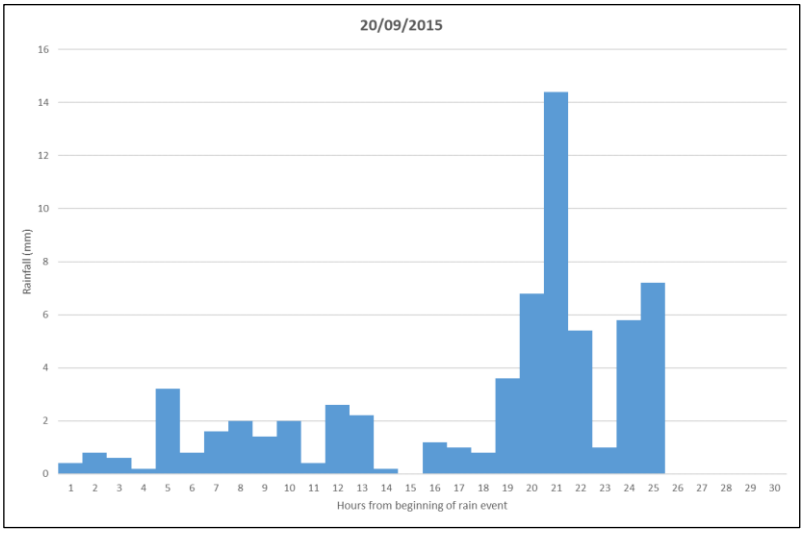

Stout St RG - 72-hour rainfall (2014-2019)
Rainfall (mm)
Date
72-hour rainfall
2 year ARI
1.58 year ARI
Scour events

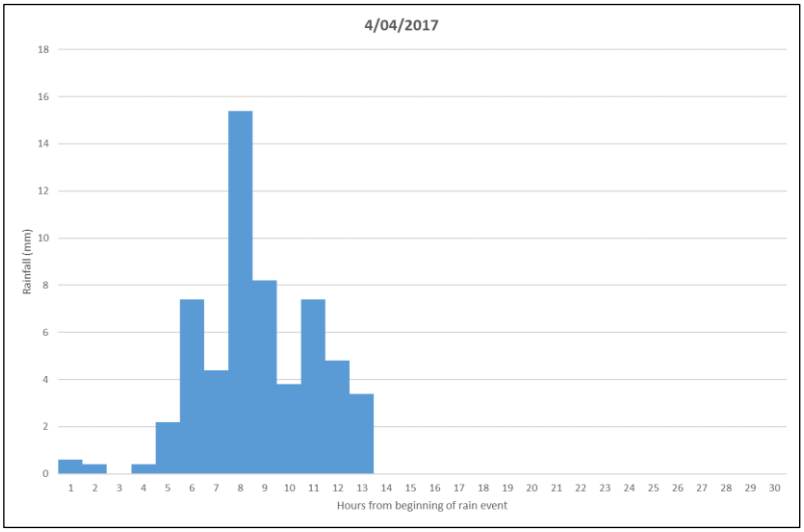
Annex D: Part 1: Hourly rainfall prior to scours being opened (Paraone Rd rain gauge)

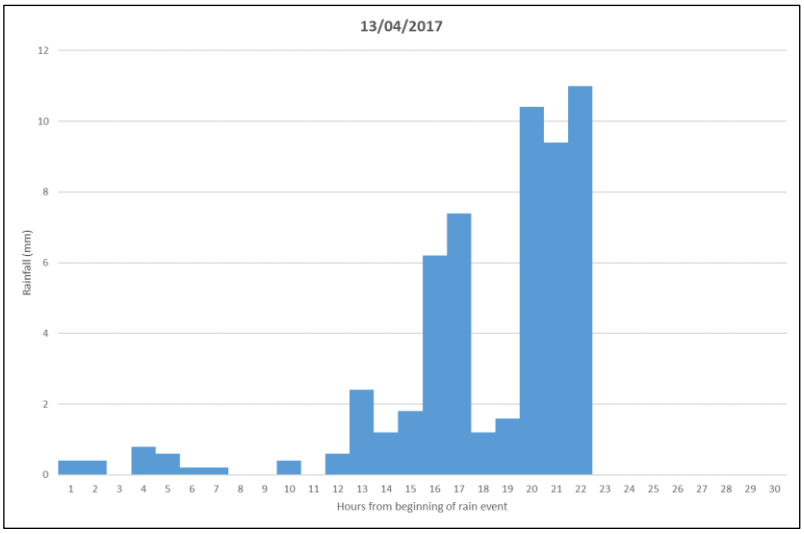


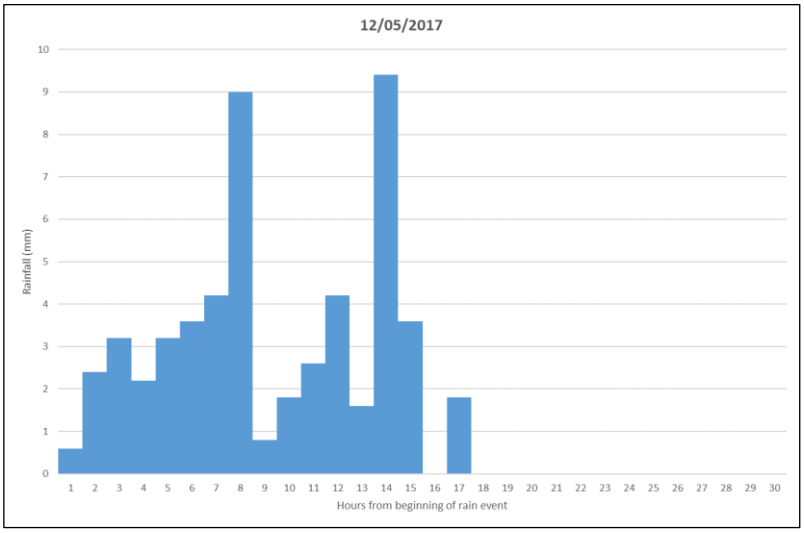


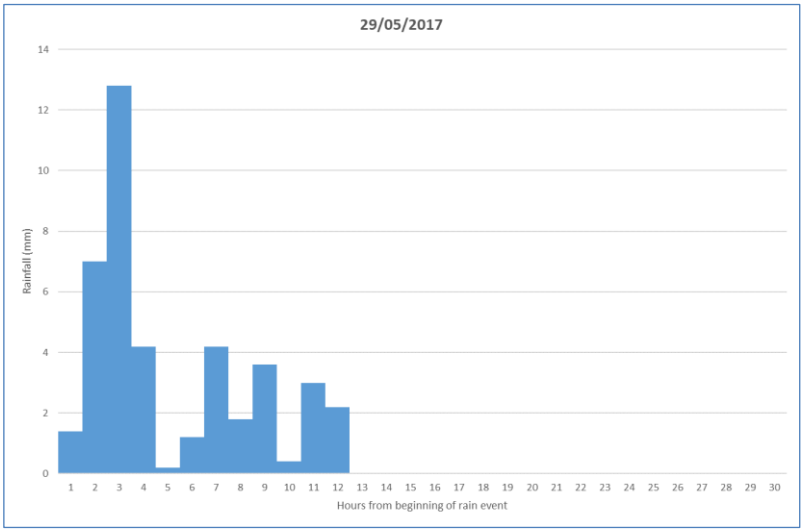


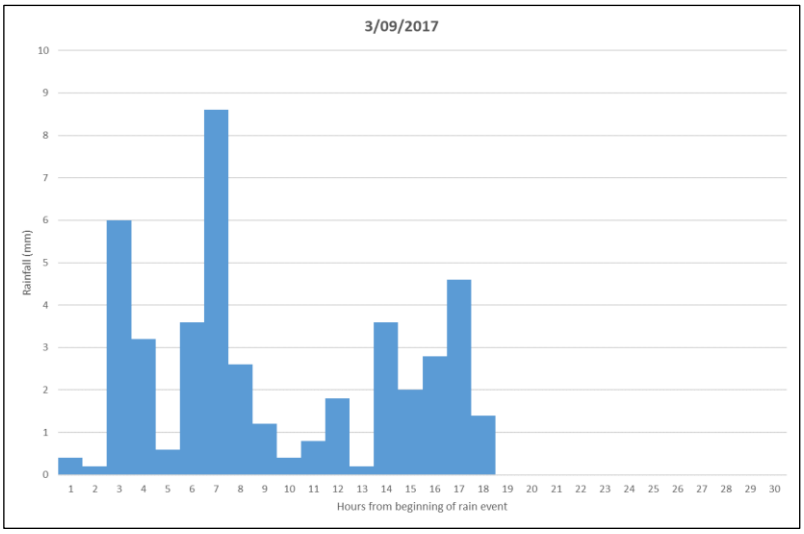

20/09/2015
Rainfall (mm)
0 2 4 6 8 10 12 14 16
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Hours from beginning of rain event

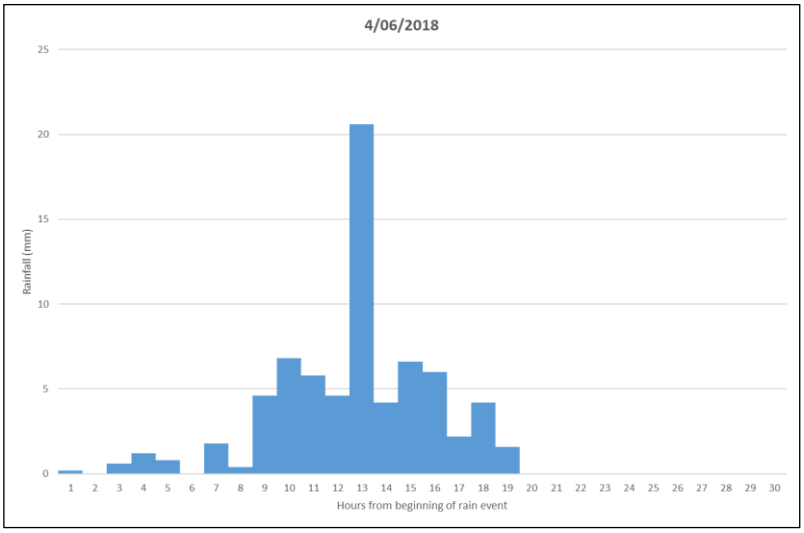

4/04/2017
Rainfall (mm)
0 2 4 6 8 10 12 14 16 18
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Hours from beginning of rain event

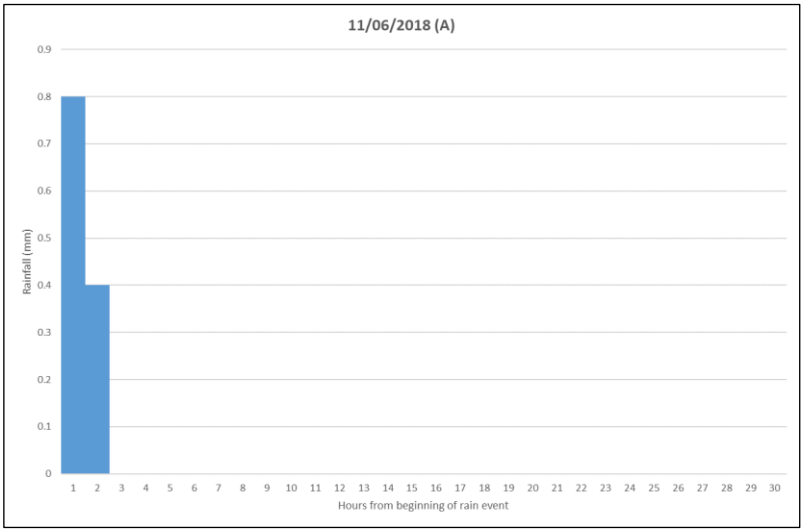

13/04/2017
Rainfall (mm)
0 2 4 6 8 10 12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Hours from beginning of rain event

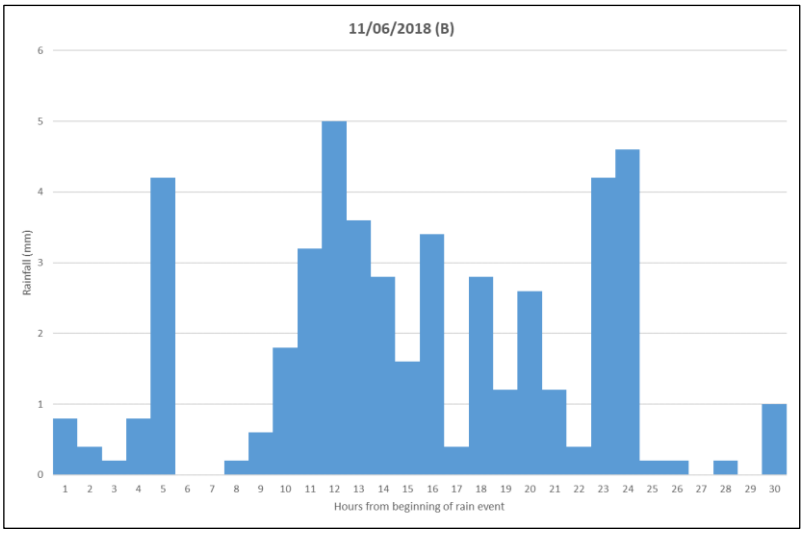

12/05/2017
Rainfall (mm)
0 1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Hours from beginning of rain event

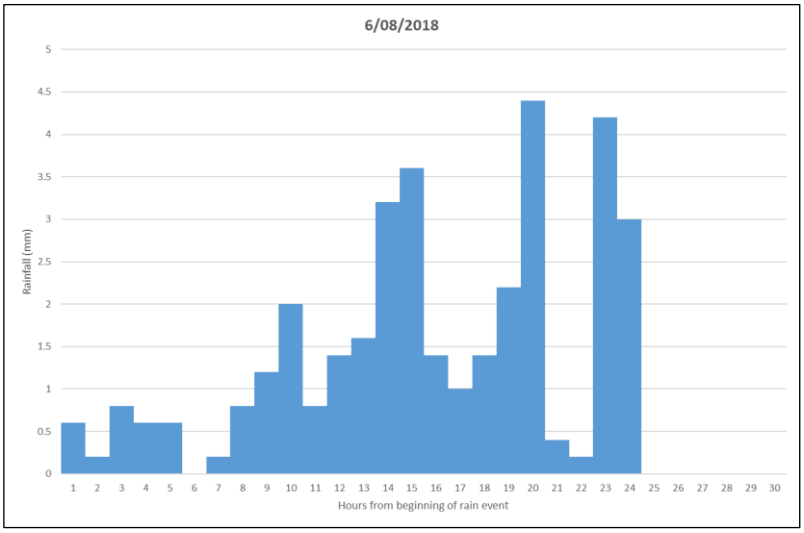

29/05/2017
Rainfall (mm)
0 2 4 6 8 10 12 14
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Hours from beginning of rain event

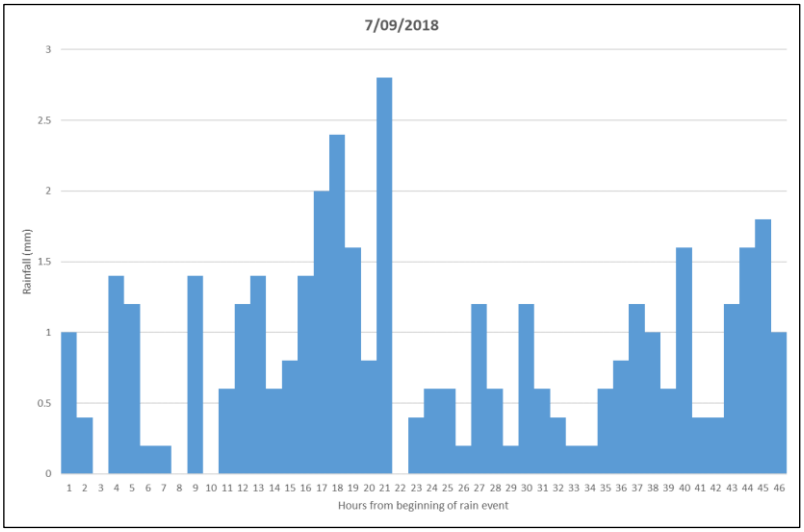

3/09/2017
Rainfall (mm)
0 1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Hours from beginning of rain event

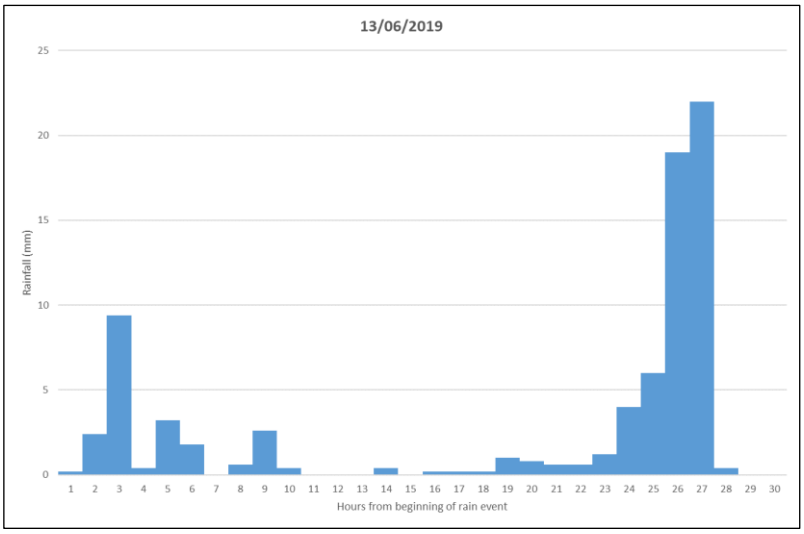

4/06/2018
Rainfall (mm)
Hours from beginning of rain event

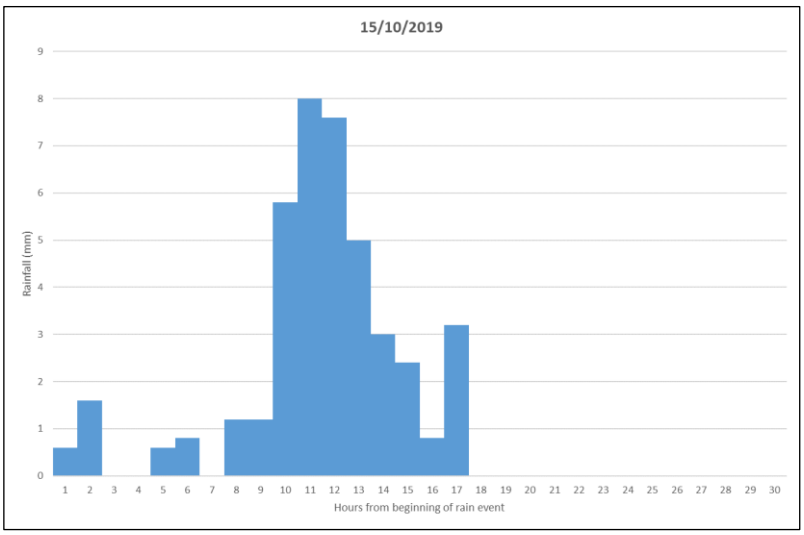

11/06/2018 (A)
Rainfall (mm)
Hours from beginning of rain event


11/06/2018 (B)
Rainfall (mm)
Hours from beginning of rain event

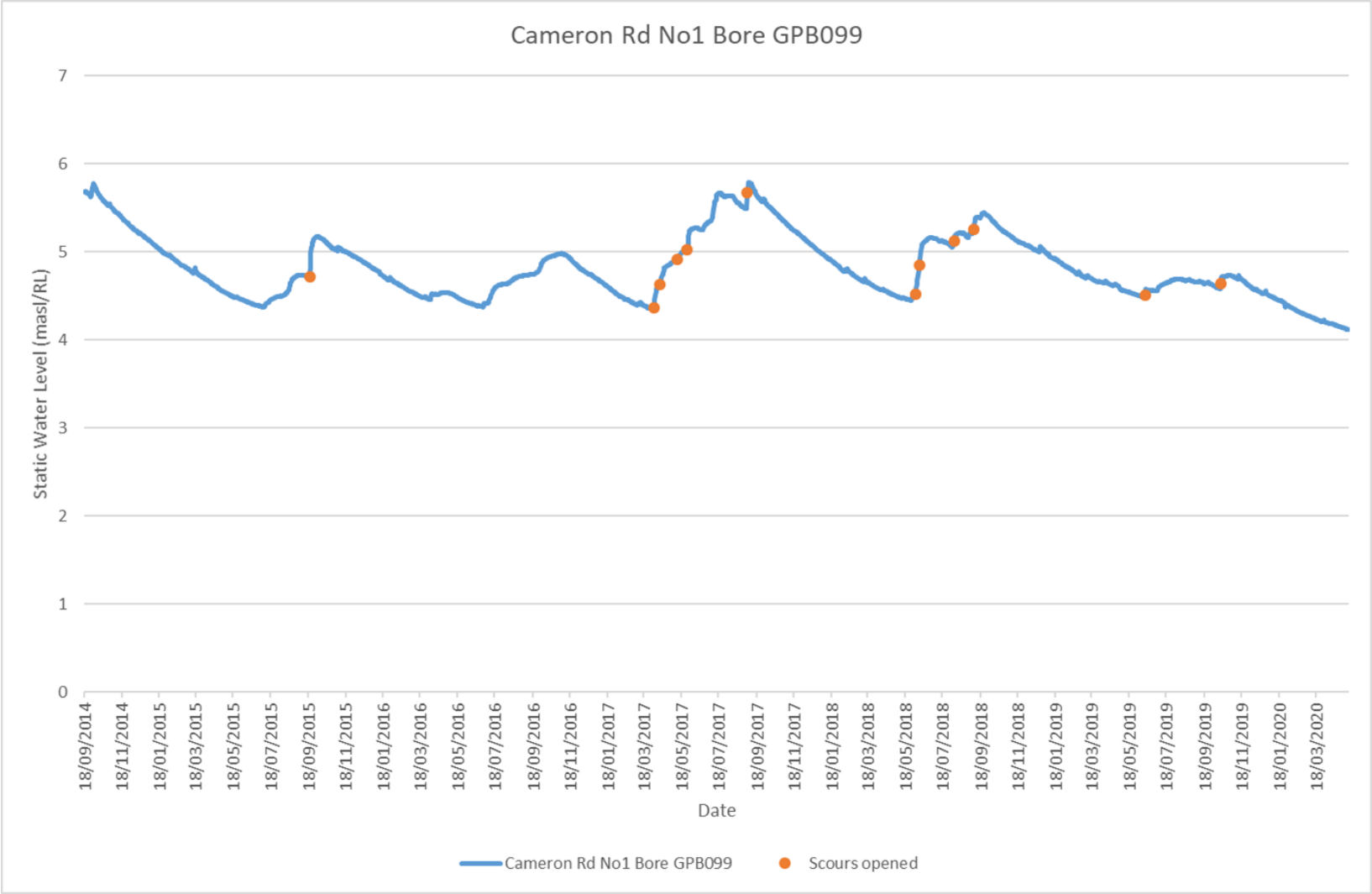

6/08/2018
Rainfall (mm)
Hours from beginning of rain event


7/09/2018
Rainfall (mm)
Hours from beginning of rain event

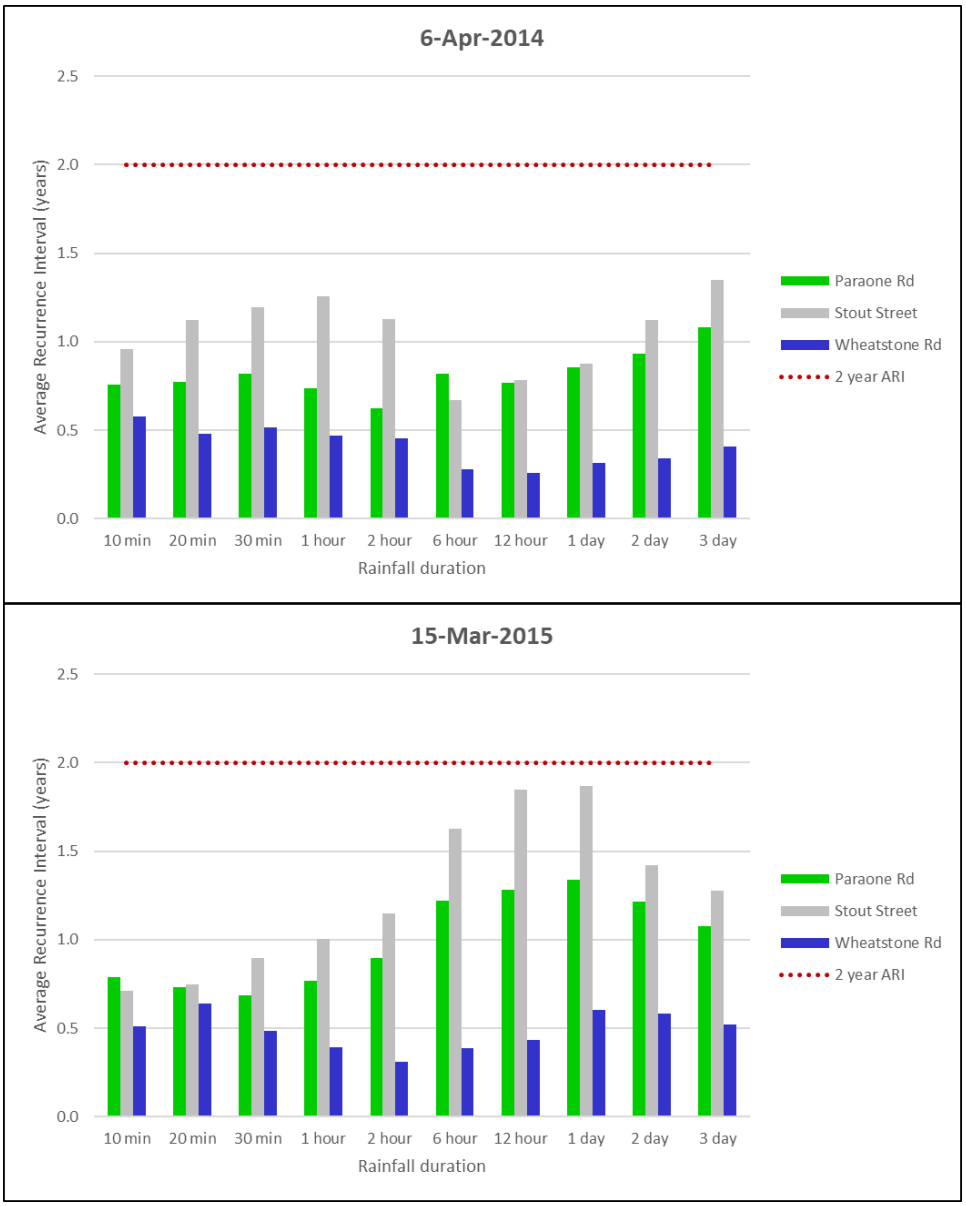

13/06/2019
Rainfall (mm)
Hours from beginning of rain event

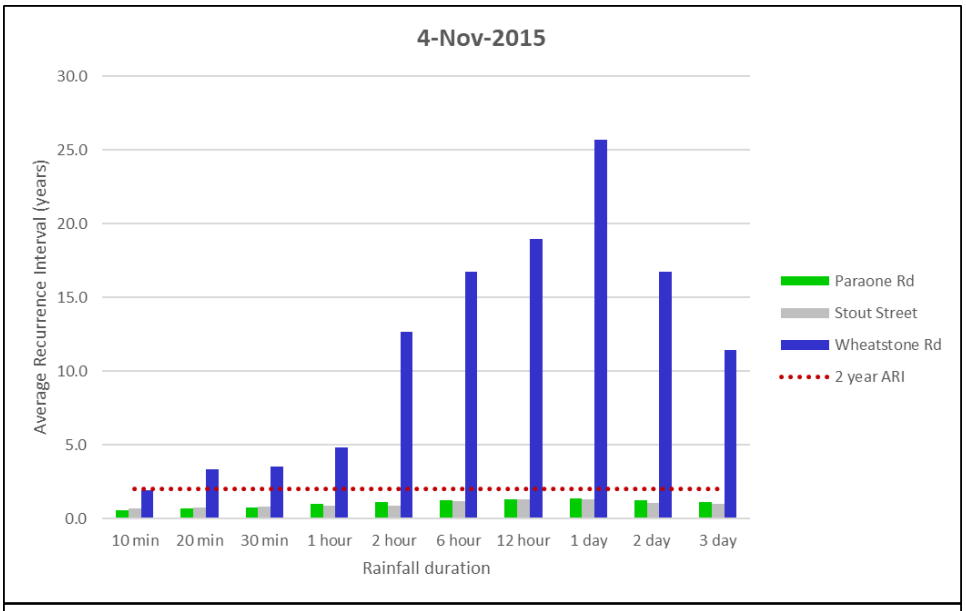

15/10/2019
Rainfall (mm)
0
1
2
3
4
5
6
7
8
9
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Hours from beginning of rain event

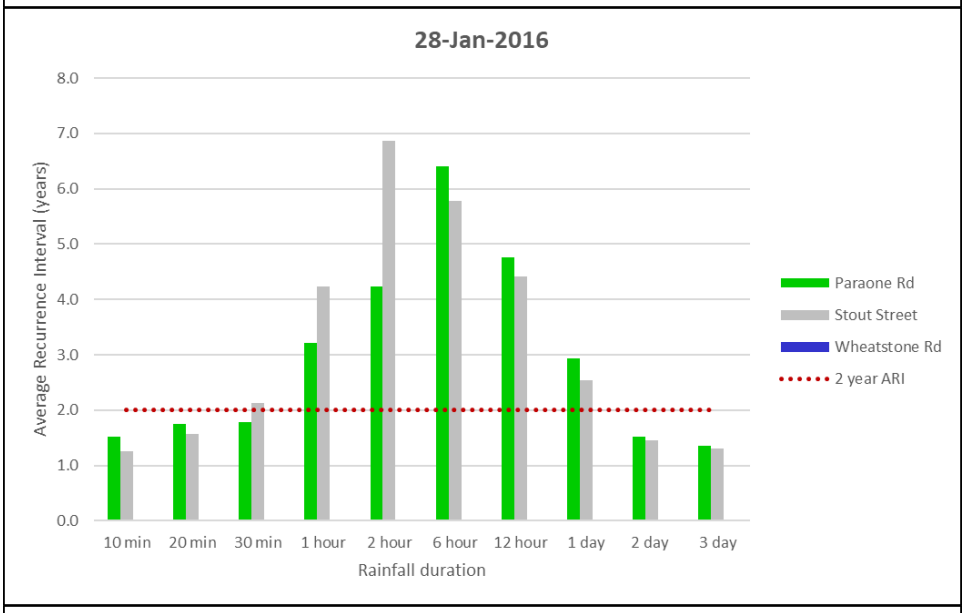
Annex E: Relationship between overflow events and shallow groundwater levels

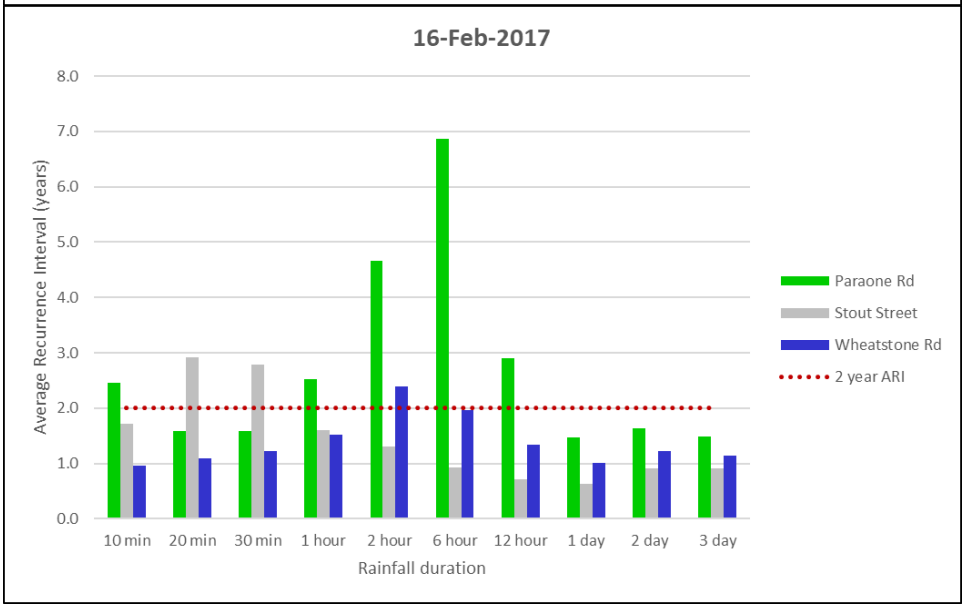


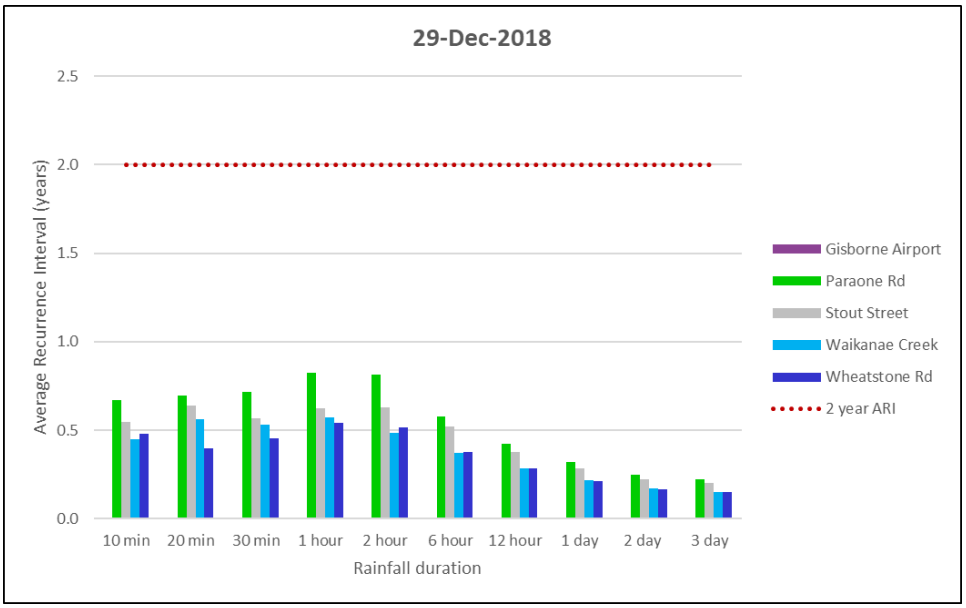
Annex F: Part 2: Examination of rainfall events when scours remained closed




4-Nov-2015
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Average Recurrence Interval (years)
10 min
20 min
30 min
1 hour
2 hour
6 hour
12 hour
1 day
2 day
3 day
Rainfall duration
Paraone Rd
Stout Street
Wheatstone Rd
2 year ARI


28-Jan-2016
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Average Recurrence Interval (years)
10 min
20 min
30 min
1 hour
2 hour
6 hour
12 hour
1 day
2 day
3 day
Rainfall duration
Paraone Rd
Stout Street
Wheatstone Rd
2 year ARI


16-Feb-2017
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Average Recurrence Interval (years)
10 min
20 min
30 min
1 hour
2 hour
6 hour
12 hour
1 day
2 day
3 day
Rainfall duration
Paraone Rd
Stout Street
Wheatstone Rd
2 year ARI


29-Dec-2018
2.5
2.0
1.5
1.0
0.5
0.0
Average Recurrence Interval (years)
10 min
20 min
30 min
1 hour
2 hour
6 hour
12 hour
1 day
2 day
3 day
Rainfall duration
Gisborne Airport
Paraone Rd
Stout Street
Waikanae Creek
Wheatstone Rd
2 year ARI