Rainfall Analysis of Perth Hailstorm 22 March 2010

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Abstract

Perth experienced possibly the most intense hail and rain storm ever recorded since European settlement on Monday 22 March 2010. The damage caused by the storm made it WA's most expensive insurance incident. To produce a record of the precipitation over the metropolitan area between official rain gauges, JDA made a request to the general public to forward their rain gauge data and a total of 120 responses was received. Analysis of the data showed that rainfall exceeded 100 year Average Recurrence Interval (ARI) over short durations (less than 1 hour) over parts of Perth – particularly the western and northern suburbs.

1. INTRODUCTION

Historically the eastern capital cities of Sydney and Brisbane have experienced impacts from severe thunderstorms and hailstorms on numerous occasions. The more southern and western capital cities of Melbourne and Perth, both with weather records dating back close to 150 years have never reported major damage from giant hail. This changed for both cities in March 2010 when, within a space of 16 days, both experienced their costliest natural disaster on record - from giant hail produced by severe thunderstorms (Buckley et.al, 2010).

The Insurance Claims total for damage in each city was approximately $AUD1billion (Insurance Council of Australia 2010), an order of magnitude higher than the cost of any previous weather related event.

On Monday 22 March 2010 Perth experienced the most intense hail ever recorded since European settlement, together with heavy rainfall. Considerable damage was caused throughout the Perth metropolitan area due to hail damaging properties and cars, as well as flash flooding.

To produce a record of the precipitation over the metropolitan area between official rain gauges, JDA sent a letter to the Editor to all WA local newspapers requesting that rain gauge data be forwarded to allow a report to be reproduced which would be distributed to all respondents. This data, referred to as "public data", is mostly from backyard non-standard rain gauges.

Official rain gauge data from Bureau of Meteorology (BOM) was collated together with pluviograph data from the WA Department of Agriculture and Food (DAFWA).

This paper summarises rainfall data for the event and discusses the rarity across a range of durations over the Perth area.

A preliminary analysis of this data is reported by Davies and Yazahmeidi (2013). This Paper presents a more in depth analysis including information on shorter duration rainfalls and the relevance of the storm event to Perth drainage design.

2. METEOROLOGICAL DESCRIPTION

The following meteorological description is taken from a summary of the event by the WA Bureau of Meteorology (BOM, 2010).

"The storms resulted as a combination of low level convergence associated with a surface trough; surface temperatures in the low to mid 30s; surface dewpoints 17-19C; and strong instability assisted by a deep mid-level low off the west coast. This low caused the steering wind for the storms to be northerly [which is unusual], ensuring that storms forming near the coast well north of Perth remained close to the coast and affected the metropolitan area.

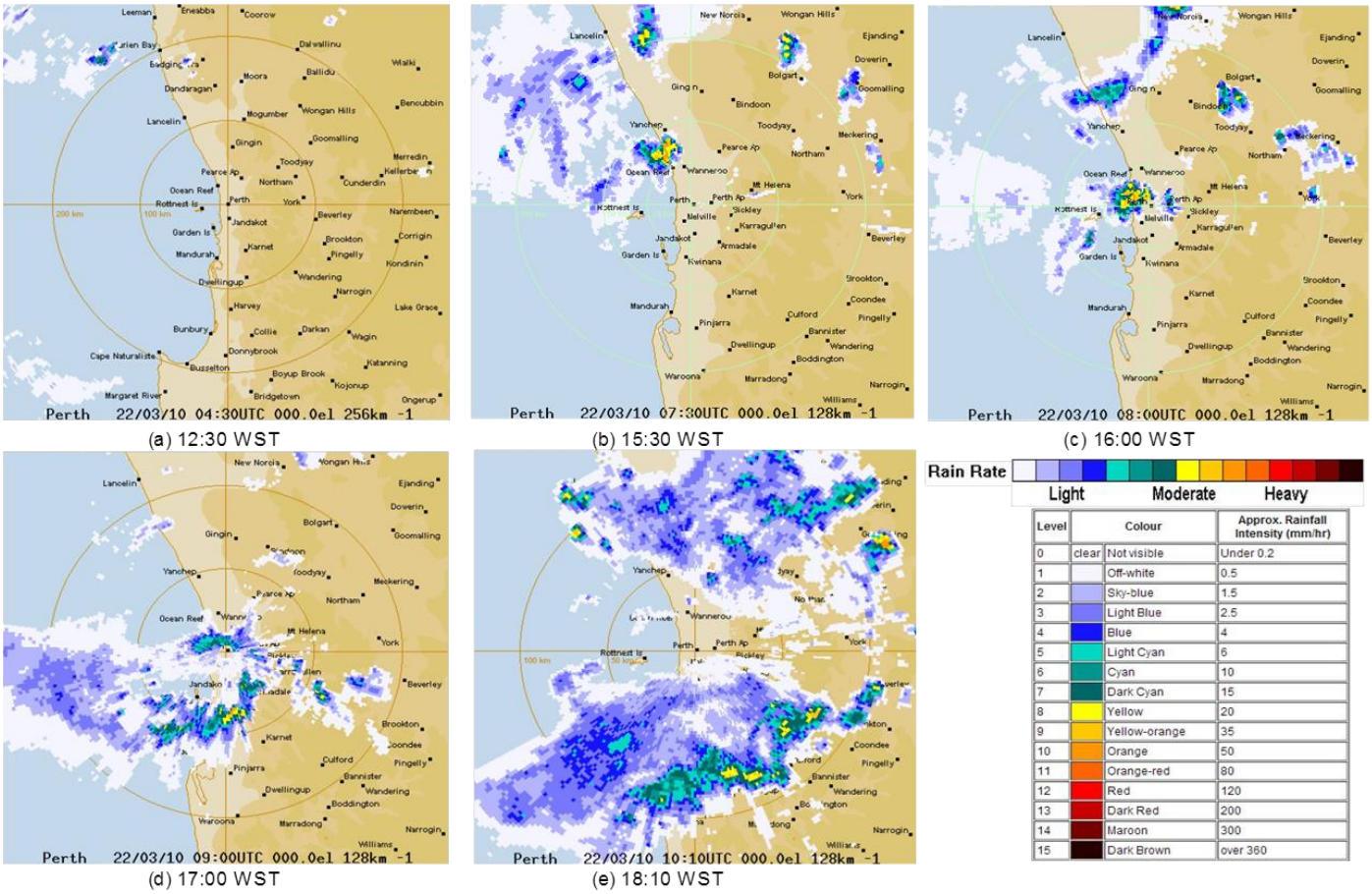
Storms developed near Badgingarra, about 180 km north of Perth just after midday (22/03/10) and

tracked to the south near the coast. The leading storm gathered intensity and reached the far northern suburbs at about 15:00 WST, and the Central Business District and western suburbs by 16:00 WST. Ocean Reef Automatic Weather Station recorded wind gusts to 120 km/h, while large hail, measured to 6 cm, dented cars and broke windscreens, windows, and light roofing material.

A second line of storms swept across Perth an hour later causing a period of intense rainfall across much of the metropolitan area. Hail accumulation in gutters exacerbated water inundation of properties.

By 18:30 WST a line of storms had developed from the initial severe storm extending along its eastern flank at the expense of the second line of storms that had weakened in its wake. These storms tracked to the south and south southeast during the evening and accounted for the intense precipitation measured south and southeast of Perth".

Figure 1 shows BoM radar imagery which depict the movement of the storm and the rate of rain. BoM uses different colours to represent rainfall intensity, ranging from off white (which has an approximate rainfall intensity of 0.5 mm/hr) to dark brown (approximate rainfall intensity of over 360 mm/hr). For example, the BoM website describes dark red as depicting heavy rain, possibly with hailstones.



Level	Colour		Approx. Rainfall Intensity (mm/hr)
0	clear	Not visible	Under 0.2
1		Off-white	0.5
2		Sky-blue	1.5
3		Light Blue	2.5
4		Blue	4
5		Light Cyan	6
6		Cyan	10
7		Dark Cyan	15
8		Yellow	20
9		Yellow-orange	35
10		Orange	50
11		Orange-red	80
12		Red	120
13		Dark Red	200
14		Maroon	300
15		Dark Brown	over 360

Figure 1: Bureau of Meteorology radars depicting the storm movement and rainfall intensity on 22/03/2010 (BoM, 2010)

- Figure 1a shows that storms developed near Badgingarra around 12:30hrs.
- Figure 1b shows the storm became intense over the northern suburbs at 15:30hrs.
- Figure 1c shows the intense storm moved over the western suburbs and metropolitan area at 16:00hrs with other storms approaching from the north. It is during this time frame (roughly between 15:30hrs to 16:15hrs) when hail fell. Hail sizes varied from 3-6cm, with a Perth record breaking size of 6cm in the suburb of Wembley (see Figure 2).
- Figures 1d & 1e show the second set of storms which brought the rain that engulfed the area from 17:00hrs and onwards into the evening: Figure 1e shows a second area of storms from the north.

The risk of hail occurring was not evident to BoM until it was too late to issue a severe hail warning.

Figure 2: Hail measuring 6 cm in Wembley

3. STORM DAMAGE

The worst damage occurred in areas having large hail in a strip extending from the northern coastal suburbs (including Currambine and Wanneroo) to Sorrento/Duncraig/Greenwood to Nollamara/Tuart Hill/Osborne Park to Floreat/Subiaco/Shenton Park/Crawley and to South Perth. For many of those suburbs, particularly from Osborne Park to Crawley, hail from 4-6 cm was large enough to break house windows and to badly damage cars including breaking windscreens. The hail also blocked gutters and drains exacerbating the flooding impacts. Many properties were inundated with water including the University of Western Australia's library. There were isolated reports of roof damage from severe winds including Canning Vale in the south eastern suburbs. Figures 3 – 6 show the examples and the damage caused by the storm.

Figure 3: Front lawn covered by hail in Shenton Park (Laurine Cooper, 2010)

Figure 4: Carpet of hail-stripped leaves in a car park at the University of Western Australia (Andrew Tan, 2010)

Figure 5: Perth City roads flooded (Michael Spencer, 2010)

Figure 6: Hail damaged car (noth-facing windows broken with significant denting) at UWA (Jarrad Seng, 2010)

4. RAINFALL IFD

A single intensity-frequency-duration (IFD) analysis for Perth (Mt Lawley) has been generated by JDA using the BOM Computerised Design IFD Rainfall System (CDRIS), which is based on pre 2013 BOM revision to IFD values (i.e. the Australian Rainfall and Runoff 1987 values) (BOM, 2013).
For example, the 100 yr Average Recurrence Interval (ARI) rainfall of 1 hr duration is 47.5 mm/hr, that is, 47.5 mm rainfall.
Results for durations up to 2 hours are presented in Table 1 and shown in Figures 7 to 9 for comparison with observed data from BOM, DAFWA and General Public respectively.
Spatial variation of design rainfall intensity across the Perth region considered is generally less than 10% (Engineers Australia, 1987). BoM (2013) design rainfall intensities are within 10% of the 1987 values and have not been analysed.

Table 1: IFD table for Perth (Mt Lawley)

DURATION (min)	INTENSITY (mm/hour) (for Perth - Mount Lawley)						
	ARI						
	1 yr	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr
5	59.0	78.0	103.0	120.0	145.0	182.0	214.0
6	54.9	72.6	95.6	112.0	135.0	169.0	198.0
15	35.8	47.0	60.5	70.1	83.4	103.1	119.8
30	24.3	31.7	40.1	45.9	54.2	66.2	76.3
45	19.0	24.7	31.0	35.4	41.5	50.5	58.0
60	15.9	20.6	25.7	29.2	34.2	41.5	47.5
90	12.3	15.8	19.7	22.2	26.0	31.3	35.8
120	10.2	13.1	16.2	18.3	21.3	25.6	29.2

Table 2: Observed intensities from BoM, DAFWA and Public data.

Duration (min)	OBSERVED INTENSITY (mm/hr) - Source, Location and JDA Reference Number										
	Bureau of Meteorology				DAFWA				Public		
	Champion Lakes #102	Perth Airport #107	Perth Metro (Mt Lawley) #106	Swanbourne #101	Medina #113	South Perth #114[1]	Floreat #115	Carabooda #116	Iluka #119	Floreat #34	Duncraig #2
5	-	-	-	-	84.0	213.6	158.4	177.6	-	-	-
6	-	-	-	-	82.0	200.0	140.0	166.0	-	-	-
15	56.8	108.8	56.0	70.4	66.0	108.0	96.8	138.4	84.8	240	120
30	36.0	66.8	52.0	43.2	33.2	-	55.6	76.8	47	120	60
45	39.3	45.9	39.3	30.0	22.7	-	37.1	52.0	31.3	80	40
60	30.4	35.2	30.4	32.4	21.6	-	35.0	39.0	26.6	60	30
90	24.0	24.7	20.3	25.9	17.2	-	31.6	40.1	29.3	40	20
120	18.9	19.0	17.7	22.7	13.5	-	24.4	31.3	22	30	15
2 hr Total	37.8	38.0	35.4	45.4	27.0	-	48.8	62.6	44.0	60.0	30.0

1. Rain gauge destroyed during event; no further data beyond 15 mins

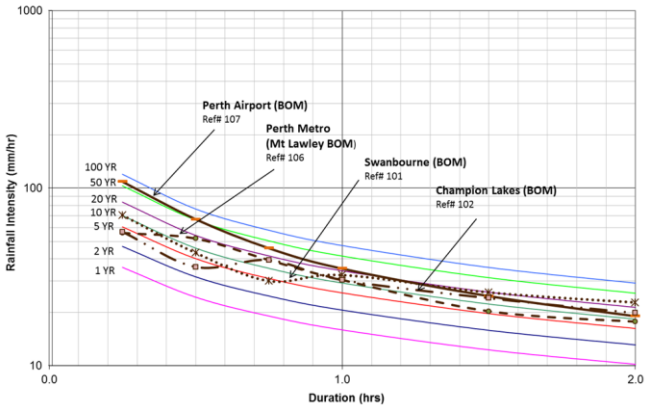


Figure 7: Perth (Mt Lawley) IFD curves with BoM data

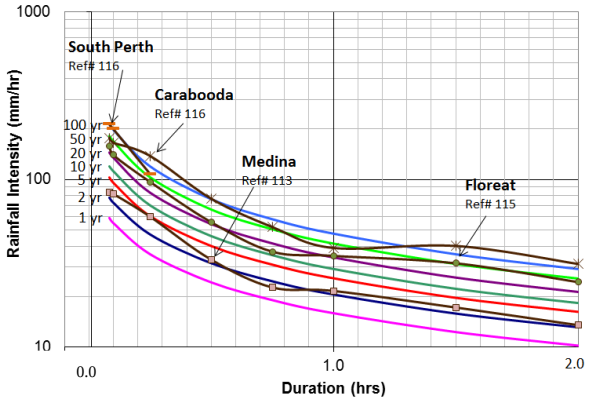


Figure 8: Perth (Mt Lawley) IFD curves with DAFWA data 22/03/2010

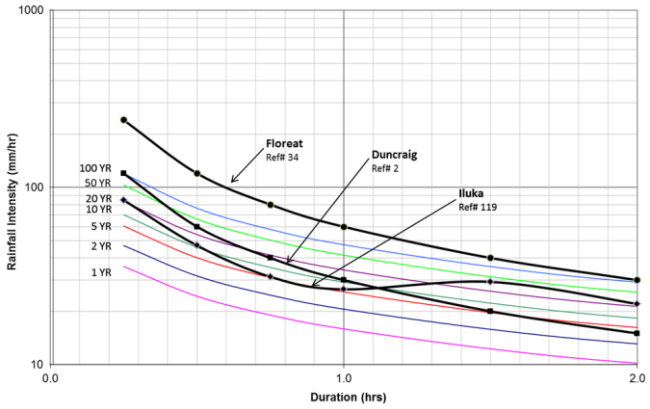


Figure 9: Perth (Mt Lawley) IFD curves with Public data 22/03/2010

5. RAIN GAUGE DATA 22/03/10

A total of 120 responses (from the public and BOM/DAFWA) were received by JDA (by email/fax/phone) extending from Yanchep in the north to Mandurah in the south and to Bakers Hill in the east, reflecting the circulation of newspapers requested to carry the request. Hail, which has an equivalent depth of water to rainfall, was not recorded by BOM, DAFWA or the Public rain gauges as hail generally bounces out of, or damages a rain gauge. Many Public Respondents did report to JDA the occurrence of hail.

The majority of responses gave only total rainfall amounts for the whole storm event. Only a few responses had rainfall amounts for shorter durations. The ARI of the storm rainfall has been analysed for durations down to 15 minutes, except for DAFWA data (down to 5 minutes). JDA assumed that the total duration of the storm at all locations was 2 hr.

Figure 7 to 9 show IFD curves with BOM, DAFWA and Public sites superimposed respectively.

Figure 7 shows that the Perth Airport intensities exceeded 50 yr ARI for durations 15 min to 30 min. Mount Lawley's highest ARI of 20 yrs occurred at the 30 min duration. Swanbourne shows its highest ARI of above 20 yrs at the 2 hr duration. and Champion Lakes shows its highest ARI between 10-20 yrs for the 1 hr, 90 min and 2 hr durations.

Figure 8 shows, that before it was destroyed, South Perth produced an ARI in excess of 100 yrs for the 5 and 6 minute durations. Carabooda experiences a greater than 100 yr ARI for the 15 and 30 minutes durations. Medina experiences a relatively low ARI for the entire storm, not exceeding the 5 yr ARI for all durations. Floreat shows it higher ARI of above 50 yrs at the 90 minute duration.

Figure 9 shows Floreat to be above the 100 yr ARI for the entire duration of the storm. Duncraig shows its highest ARI of above 100 yrs for the 15 minute duration and Illuka shows a peak ARI of just

below 50 yrs for the 90 minute duration.

Figures 10 to 13 show maps of rainfall ARI for durations of 15, 30, 60 and 120 minutes respectively. They also show approximate ARI contours. The BOM, DAFWA and Public data are in good agreement, and the latter allows a spatial interpretation enhancement compared with using only BOM and DAFWA data alone.

Figure 10 shows that for a 15 minute duration storm, the western and northern suburbs had high ARIs, with Floreat, Wembley Downs, Leederville, Sorrento, Duncraig, Hillarys and Carabooda all having greater than a 100 yr ARI.

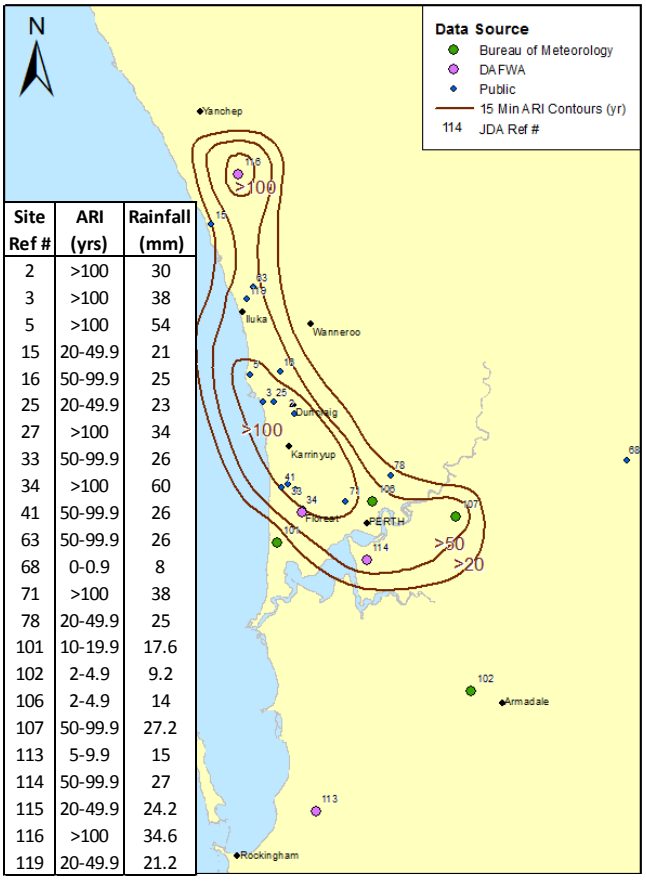
Figure 11 shows that for a 30 minute storm, the northern and a portion of the western suburbs had high ARIs. Floreat, Hillarys, Kallaroo, Wanneroo and Carabooda all had greater than a 100 yr ARI.

Figure 12 shows that for a 1 hour storm, once again, the western and northern suburbs had high ARIs, with Floreat, Woodlands, Hillarys, Kallaroo and Kingsley all having greater than a 100 yr ARI.

Figure 13 shows that for a 2 hour duration storm, the western and northern suburbs, as well as a few pockets in the south had high ARIs. Towards the west, West Perth, Leederville, West Leederville, Jolimont, Shenton Park, Wembley, Wembley Downs, Floreat, City Beach and Cottesloe had greater than 100 yr ARIs. Towards the north, Mount Hawthorne, Woodlands, Tuart Hill, Kingsley, Kallaroo Joondalup, Kinross, Quinns Rocks and Carabooda had great than 100 yr ARIs. In the south, Palmyra, Gosnells and Serpentine had greater than 100 yr ARIs

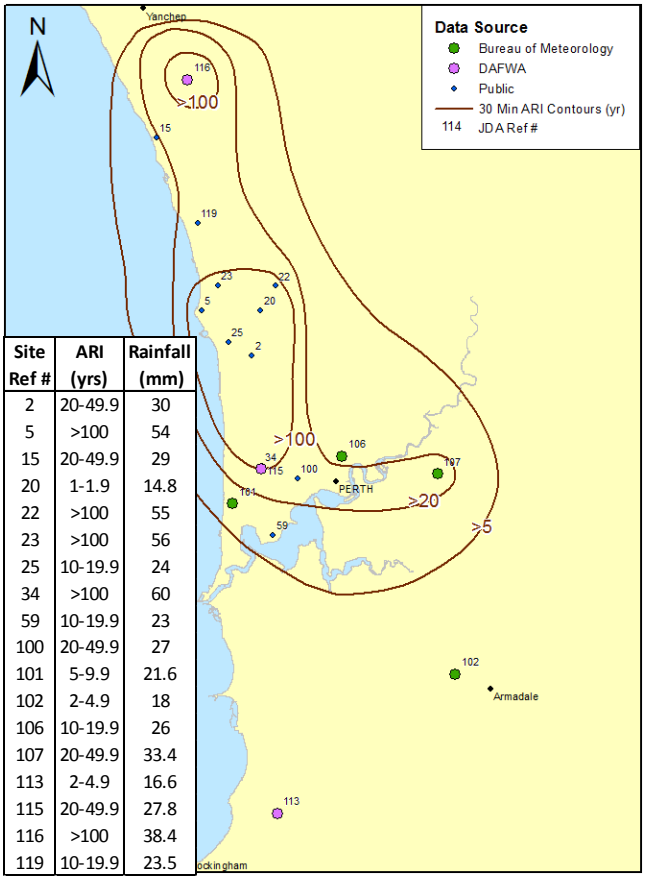
Figure 14 depicts the area over which hail was reported, showing that central Perth, western suburbs, northern suburbs, and some suburbs south of the river received hail.

It is clear that the highest ARIs, exceeding 100 yr ARI, were concentrated in 2 distinct areas: one extending over the western suburbs, north to south from Karrinyup to Cottesloe, and extending east to East Perth. The other area is further north, extending from Joondalup south to Duncraig, and from the coast to Wanneroo.



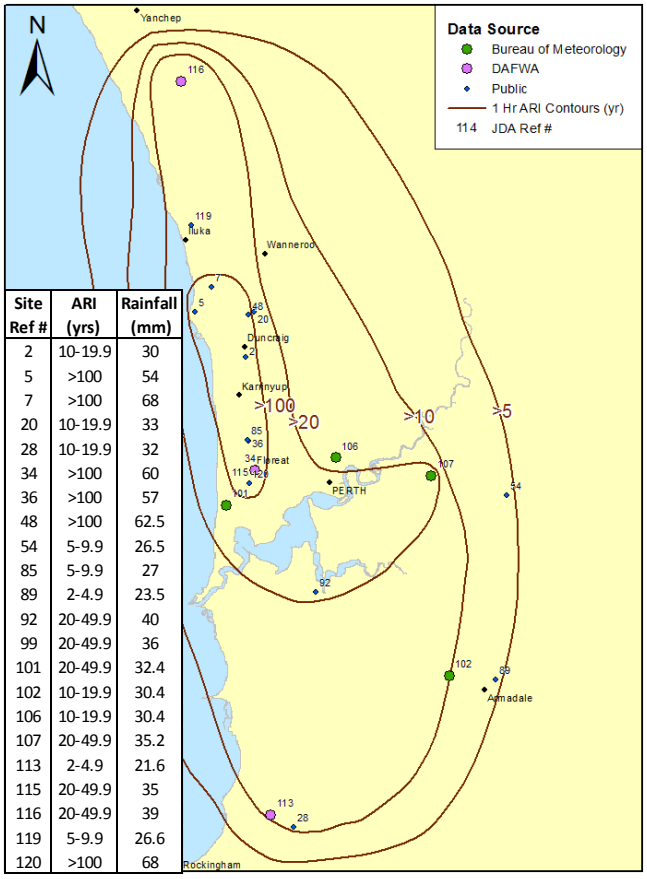
Site Ref #	ARI (yrs)	Rainfall (mm)
2	>100	30
3	>100	38
5	>100	54
15	20-49.9	21
16	50-99.9	25
25	20-49.9	23
27	>100	34
33	50-99.9	26
34	>100	60
41	50-99.9	26
63	50-99.9	26
68	0-0.9	8
71	>100	38
78	20-49.9	25
101	10-19.9	17.6
102	2-4.9	9.2
106	2-4.9	14
107	50-99.9	27.2
113	5-9.9	15
114	50-99.9	27
115	20-49.9	24.2
116	>100	34.6
119	20-49.9	21.2

Figure 10: 15 min duration rainfall



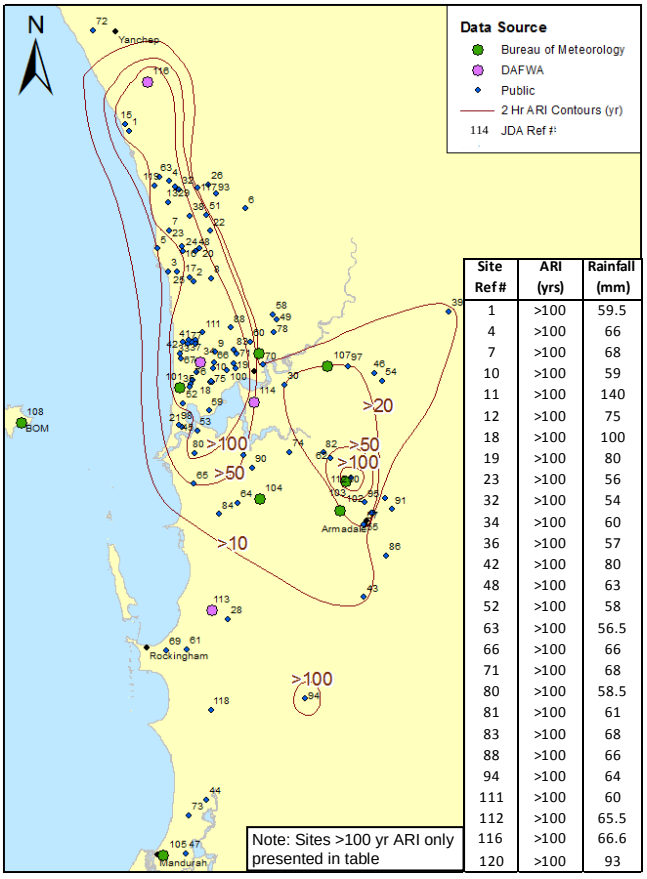
Site Ref #	ARI (yrs)	Rainfall (mm)
2	20-49.9	30
5	>100	54
15	20-49.9	29
20	1-1.9	14.8
22	>100	55
23	>100	56
25	10-19.9	24
34	>100	60
59	10-19.9	23
100	20-49.9	27
101	5-9.9	21.6
102	2-4.9	18
106	10-19.9	26
107	20-49.9	33.4
113	2-4.9	16.6
115	20-49.9	27.8
116	>100	38.4
119	10-19.9	23.5

Figure 11: 30 min duration rainfall



Site Ref #	ARI (yrs)	Rainfall (mm)
2	10-19.9	30
5	>100	54
7	>100	68
20	10-19.9	33
28	10-19.9	32
34	>100	60
36	>100	57
48	>100	62.5
54	5-9.9	26.5
85	5-9.9	27
89	2-4.9	23.5
92	20-49.9	40
99	20-49.9	36
101	20-49.9	32.4
102	10-19.9	30.4
106	10-19.9	30.4
107	20-49.9	35.2
113	2-4.9	21.6
115	20-49.9	35
116	20-49.9	39
119	5-9.9	26.6
120	>100	68

Figure 12: 1 hr rainfall duration



Site Ref #	ARI (yrs)	Rainfall (mm)
1	>100	59.5
4	>100	66
7	>100	68
10	>100	59
11	>100	140
12	>100	75
18	>100	100
19	>100	80
23	>100	56
32	>100	54
34	>100	60
36	>100	57
42	>100	80
48	>100	63
52	>100	58
63	>100	56.5
66	>100	66
71	>100	68
80	>100	58.5
81	>100	61
83	>100	68
88	>100	66
94	>100	64
111	>100	60
112	>100	65.5
116	>100	66.6
120	>100	93

Figure 13: 2 hr rainfall duration

The greater number of locations <100 yr ARI for the 2 hr duration (Figure 13) than for shorter durations, is due to public data not specifying actual durations.

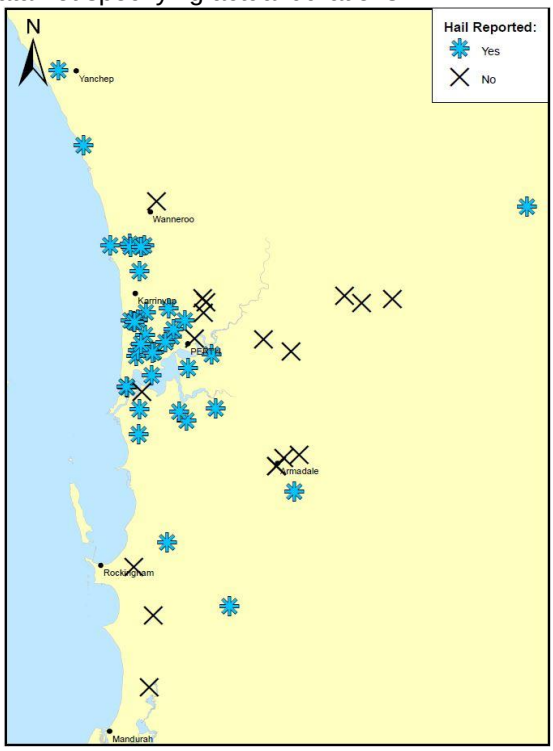


Figure 14: Reported hail extent

6. IMPLICATIONS FOR STORMWATER DRAINAGE DESIGN

The short duration (<1hr) rainfalls during the event on 22 March 2010 in Perth were the highest on record over large areas of the City. Small catchments, including roofs, driveways and local streets were worst affected by the high intensity short duration rainfall. Drainage basins were generally not filled due to the small total volume of runoff.

Buckley et.al (2010) remarked that the storm track across Perth on 22 March 2010 almost optimized (maximized) damage: coincidentally the Melbourne storm track on 6 March 2010 also approximated a track that would maximize damage. Buckley et.al (2010) suggests that even if climate change is partly responsible for these two thunderstorms in Perth and Melbourne, it is highly unlikely that future storm tracks would concentrate damage on such high value areas.

7. CONCLUSIONS

The rain associated with the severe storm in Perth on the 22/3/10 exceeded 100 yr ARI in several locations – particularly in the western and northern suburbs.

Combining BOM, DAFWA and Public data increased the spatial coverage of our understanding of the storm event particularly over short durations which are critical to storm water issues for small catchments including roofs, driveways and local streets.

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