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REPORT

Priority Rivers – Rainfall Assessment

Prepared for Northland Regional Council

MARCH 2010

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Northland Regional Council

Priority Rivers - Rainfall Assessment

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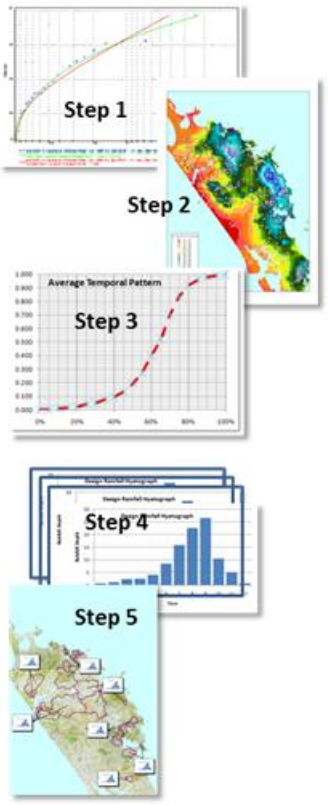
1 Objective

The objective of the rainfall assessment is to provide design rainfall estimates for all of the priority catchments for input to rainfall runoff models.

Design rainfall estimates are required for each catchment for 10, 50, 100 and 200 year ARI events and durations ranging from 1 to 24 hours.

To produce the rainfall time series several tasks were performed:

1. Perform frequency analysis of long-term rain gauge records to determine rainfall for specific event durations and return periods.
2. Compare results of at site frequency analysis with results from HIRDS* and determine a correction factor for HIRDS.
3. Determine a normalised temporal pattern of storm rainfall against time from long-term rainfall intensity records, (available only at a few specific locations in Northland).
4. Use the normalised temporal pattern (Step 3) and factored HIRDS output (Step 2) to generate rainfall depth versus time characteristics (Hyetographs) for a range of different ARI and event durations.
5. Use output from step 4 to give hyetographs at representative locations to drive hydraulic models of each catchment.



*HIRDS: High Intensity Rainfall Design System, NIWA

2 Review and Assessment of Available Data.

Intensity rainfall data and daily observer records were provided by NRC. Table 1 lists the data files received.

Table 1: Summary of Data Received

Data Received via	File Name	File Contained within Zip File	Comment
FTP Site			
	NRC Rivers and Rainfall.zip	NRC auto waterlevel site list.xls	Description of 60 waterlevel site
		hydro_rainfall_sites_bycatchment.xls	Description of 138 sites
		All Rainfall sites E and N.xls	Description of 265 sites
		27 comments files	TIDEDA comment files
		NIWA RAINFALL .doc	Description of contents of NIWA_rain.MTD
		NRC Daily Rainfall sites.doc	Description of NRC Daily Rainfall.zip
		NRC Automatic rainfall sites.doc	Description of NRC Auto Rainfall.zip
		NIWA_rain.MTD	TIDEDA data for 40 gauges (daily and auto)
		NRC Daily Rainfall,zip	56 xml files
		NRC Auto Rainfall.zip	20 xml files
		12 zipped xml files	12 xml files
Email			
	Additional Rainfall Data and doc.zip	Additional Rainfall Data.zip	44 xml files
		NRC Extra rainfall sites.doc	Description of Additional Rainfall Data.zip
		Rest of Northland rainfall Kathy Dale.xls	Description of 171 daily sites
	NIWA_3722.zip	3722 comments.txt	Comments file
		3722.mtd	TIDEDA data for 1 flow site
	NIWA_47804.zip	47804 comments.txt	Comments file
		47804.mtd	TIDEDA data for 1 flow site
	NIWA_NRC_rain_20090527.zip	NIWA_NRC_rain_20090527.mtd	TIDEDA data for 124 Rainfall Sites
		NIWA_NRC_rain_20090527.att	TIDEDA attribute file
	Rest of Northland rainfall Kathy Dale.xls		Same as supplied in Zip file

2.1.1 Daily Rainfall Data

There are over 200 open and closed daily gauges in the region. Daily gauges are read at 9:00am each day and rainfall depths manually recorded and passed to the Regional Council or NIWA. Table 2 lists the daily gauges currently open and used in the rainfall analysis and Figure 7 shows the locations of these gauges.

Table 2: Daily Raingauges Used in Frequency Analysis

Site no	Site name	NZMG Easting	NZMG Northing	Record Begin	Record End	Years of Record
532311	Takahue Top	2544000	6665300	71	09	38
532611	Waihou Valley	2574200	6656900	79	09	30
532710	Puketi Road	2579200	6659600	63	09	46
535512	Waimamakau	2559223	6625979	81	09	28
543012	Whangae	2604700	6649700	81	09	28
543110	Opua	2612300	6652400	93	09	16
544311	Peach Orchard Road	2628600	6635100	81	09	28
545111	Dawson (Needhams)	2615000	6632800	78	09	31
545213	Morgan	2619700	6630300	74	09	35
546315	Hansen	2631800	6612700	87	09	22
546412	Ferguson	2641900	6619800	68	09	41
547214	Totara Place	2616700	6603800	78	09	31
547219	Cemetery Road	2623500	6604600	79	09	30
547223	Redwood	2619200	6602900	83	09	26
547411	Parua Bay	2642100	6602500	86	09	23

2.1.2 Intensity Rainfall Data

Intensity rainfall data is recorded by “automatic” or “intensity” instruments. They generally measure rainfall in 0.5mm increments and record the time that the rain fell. Older types of intensity raingauges use a graph to plot increasing water level within a container versus time. More recently installed gauges use a tipping bucket to record the date and time of rainfall. There are far fewer intensity instruments than daily gauges in Northland and this type of record is only available from the 1980’s through to the present day.

Table 3 lists the intensity raingauges with sufficient recent data suitable for undertaking frequency analysis. Appendix 1 is a list of all past and present intensity raingauges in the region.

Table 3: Intensity Raingauges Used in Frequency Analysis

Site no	River Catchment	Site name	NZMG Easting	NZMG Northing	Record Begin	Record End	Years of Record
545201	Wairau	Puhi Puhi	2626492	6631876	86	09	23
546301	Hatea	Glenbervie Forest	2632545	6615258	88	09	21
546416	Ngunguru	Polerain/Dugmores	2640443	6621234	87	09	22
640436	Ahuroa	Brynderwyn	2638251	6572082	87	09	22
532821	Maungaparerua	Tyrees Ford	2591200	6662400	81	09	28
533817	Waitangi	Ohaeawai	2590215	6648961	98	09	11
532711	Waipapa	Puketi	2578500	6664600	83	94	9
534722	Opahi	Cocksfoot	2576300	6643600	85	94	9
543010	Waitangi	McDonald Road	2604645	6651732	86	08	22
547338	Whangarei	Robert Str	2630500	6607500	95*	04	9
534807	Waima	Kaikohe EDR	2584973	6642547	85	09	18
547342	Whangarei	City Automatic	2630500	6607500	88	09	18

*Daily from 1989

Figure 1 shows the priority catchment boundaries and the locations of the gauges in Table 3. Data are available from gauges on the east coast but there is a lack of long term gauges on the west coast. There is almost a five year gap in data from the Kaikohe EDR record between 2002 and 2007 and there is a gap between 1993 and 1995 in the City Auto gauge record.

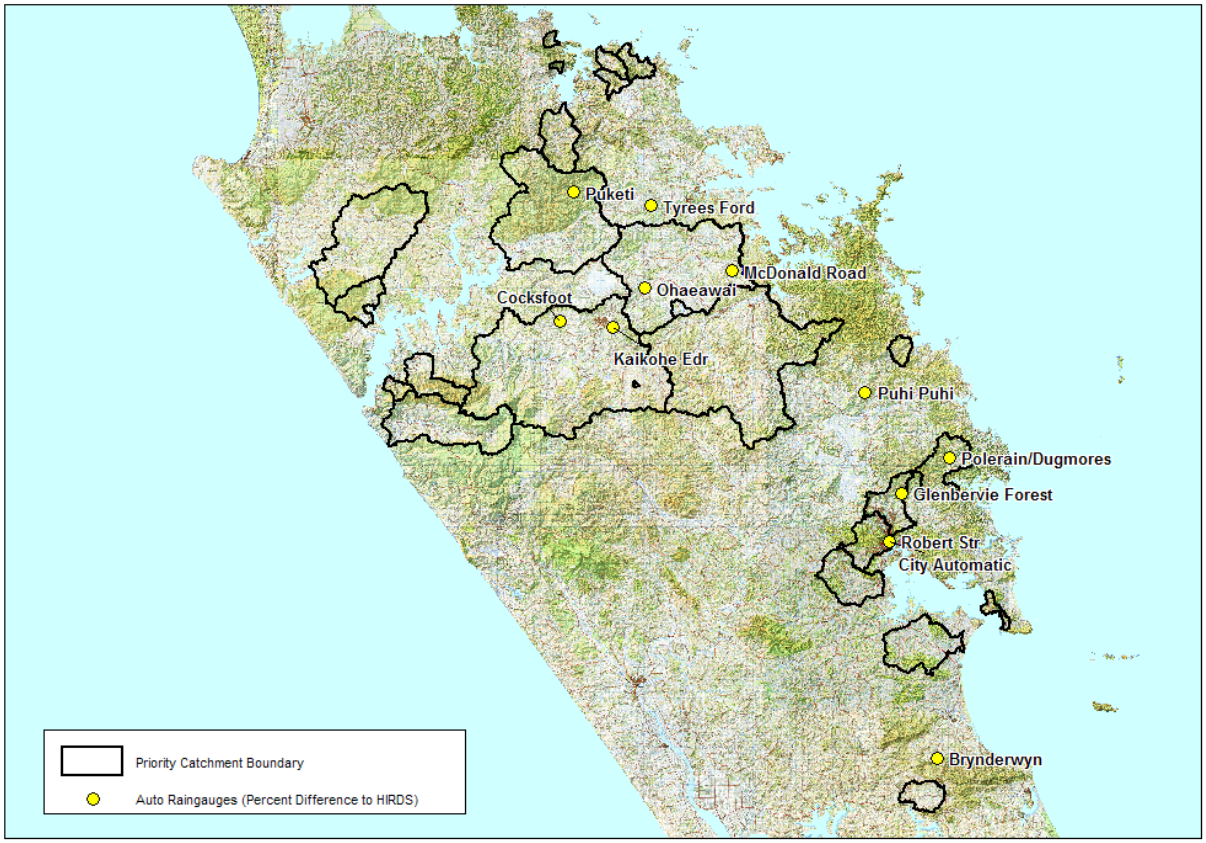


Figure 1: Location of Long-Term Intensity Raingauges

2.1.3 Cumulative Plots

Cumulative plots of selected raingauges were produced and are plotted in Figure 2. Comparisons of cumulative plots can identify significant problems with a raingauge. For example if vegetation growth or the construction of a fence or building occurs which obstructs the gauge this is likely to show up when compared with other gauges. The data plotted in Figure 2 shows rainfall of reasonable quality with no significant errors.

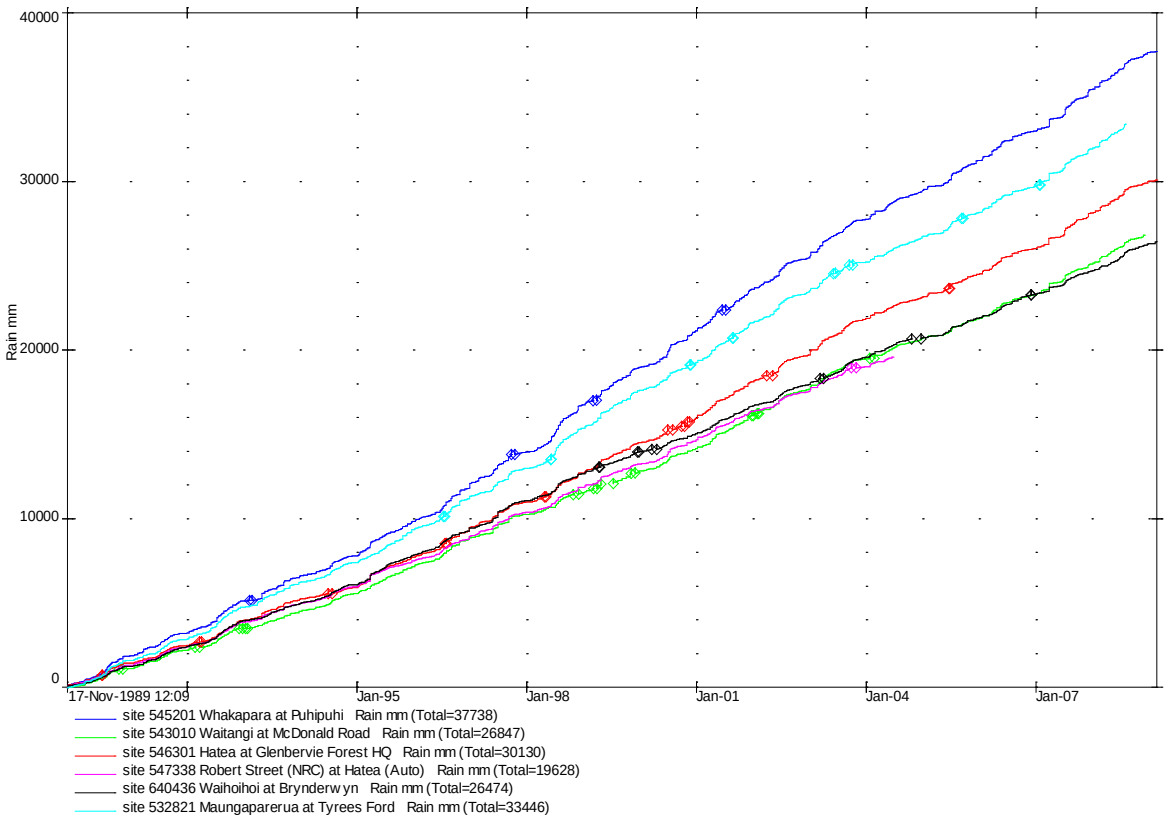


Figure 2: Cumulative Rainfall Plots

2.2 Frequency Analysis

Frequency analysis was carried out on data from each of the intensity raingauges in Table 3 for durations from 1 to 24 hours and ARI's from 10 to 100 years. The analysis was also carried out on the daily gauge data listed in Table 2, for 24 hour 100 year ARI events.

The software database and analysis software TIDEDA was used to extract annual maxima for each duration and undertake the frequency analysis. An example of the results of the analysis is given in Figure 3. It was found that in general the Extreme Value Type 1 (Gumbel) distribution fit the data best and was adopted for all analysis.

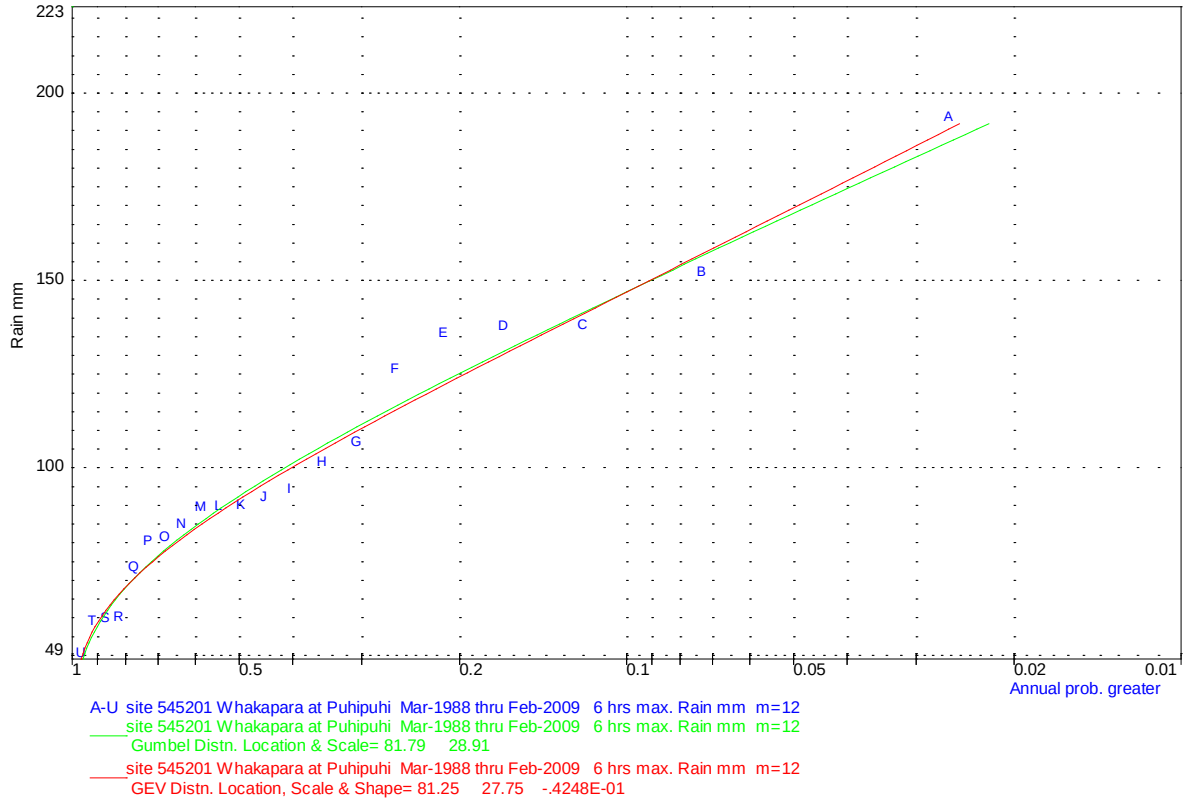


Figure 3: Example of Rainfall Frequency Analysis

2.3 Spatial Distribution

To assess the distribution of storm rainfall across the region a grid of 24 hour duration, 100 year ARI rainfall depths was obtained from NIWA. It is based on the same data as used in HIRDS V2. The grid was converted to 10mm interval rainfall contours to provide a map of the variation in rainfall depth across the region and within individual catchments. Figure 4 shows the locations of raingauges used in the NIWA assessment and rainfall contours. The contours show significantly higher storm rainfall recorded on the east coast.

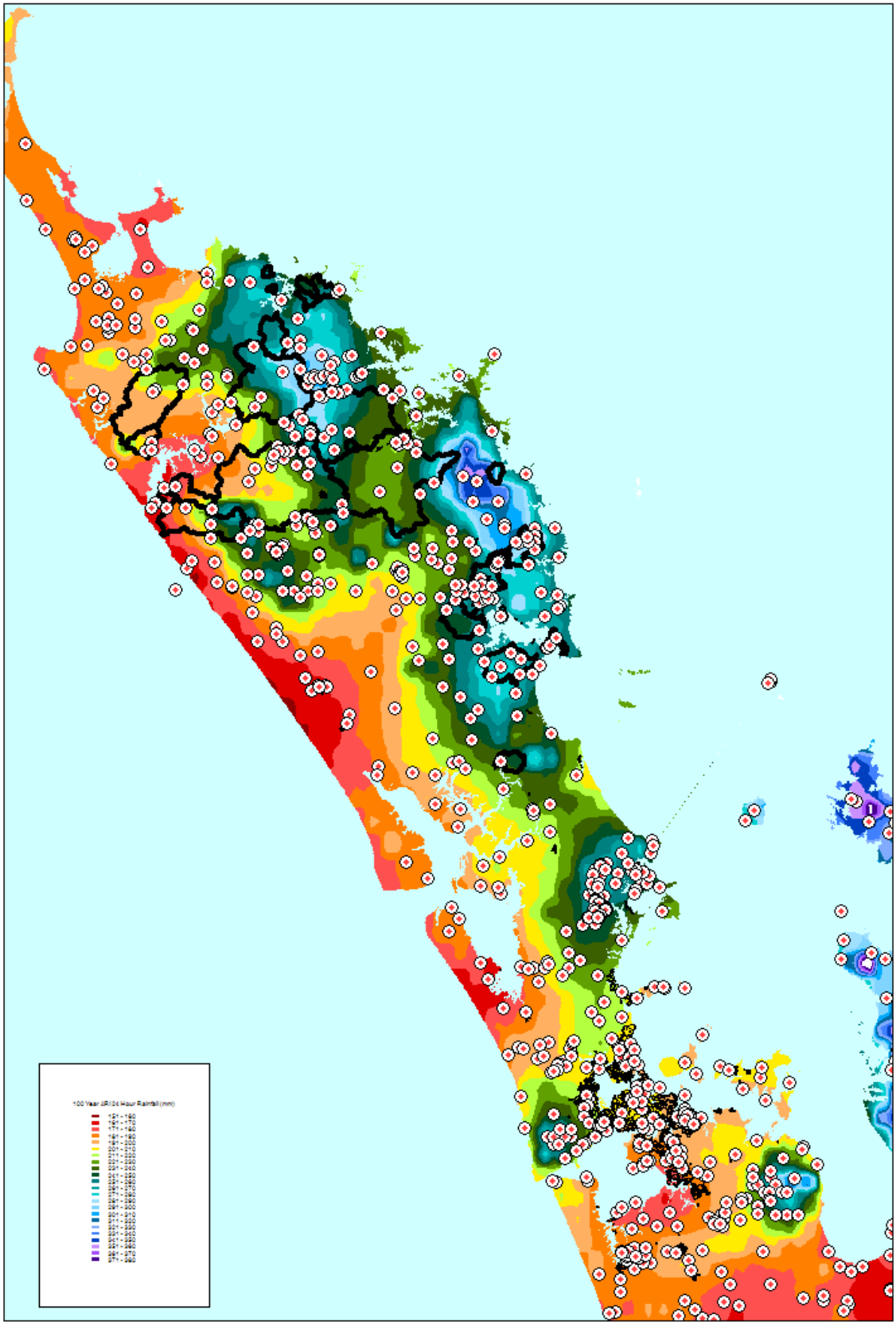


Figure 4: 100 yr 24 hr ARI Rainfall Distribution

2.3.1 Intensity Raingauges

The results of the rainfall frequency analysis were compared with output from NIWA's High Intensity Rainfall Design System (HIRDS V2) so that a correction factor could be applied for any differences between HIRDS V2 and more up to date data.

HIRDS V2 is a procedure for estimating rainfall frequency at any point in the country. It is based on regional frequency methods which have the advantage of minimising the impact of uncertainty associated with individual records. Combining records generally reduces uncertainty and produces more reliable estimates. HIRDS V2 uses median annual maximum rainfall as the index rainfall from which regional growth curves are developed to give estimates for various annual exceedance probabilities. These parameters are based on data from over 500 daily and intensity raingauges in the Northland region up to the end of 2000. Figure 4 gives the location of these gauges.

The results from HIRDS V2 were compared with frequency analysis for all 12 intensity gauges and showed that on average HIRDS V2 values were 8% lower than the frequency analysis results. It also showed that there was a marked difference in results between the 8 east coast gauges and the 4 raingauges further inland. The average was calculated for ARI events of 10, 20, 50, and 100 years and durations of 1, 2, 6, 12 and 24 hours.

The average difference between HIRDS V2 and the results of the frequency analysis for the eight gauges on the east coast was 15%. For the four gauges in the more central part of the region the difference was -7%. The four gauges in the central area had generally shorter records than the east coast gauges and either had significant gaps (Kaikohe EDR) or ended in 1994 (Cocksfoot and Puketi).

Table 4 summarises the results of the analysis for each gauge. "All durations and ARI's" refers to 1, 2, 6, 12 & 24 hours and 10, 20, 50 and 100 years ARI. The data is also shown in Figure 5. The number after the site name in Figure 5 is the percent difference between the frequency analysis and HIRDS V2.

Table 4: Comparison of HIRDS V2 and Frequency Analysis of Intensity Data

	Difference between Frequency Analysis and HIRDS V2	
East Coast Gauges	All durations and ARI's	100yr 6hr Event
Maungaparerua at Tyrees Ford	9%	4%
Whakapara @ Puhipuhi	29%	20%
Hatea @ Glenbervie	16%	15%
Waihoihoi @ Brynderwyn	21%	24%
Ngunguru @ Dugmores Rock	24%	10%
Waitangi @ McDonald Road	17%	16%
Whangarei @ Combined Auto	0%	4%
Hatea @ Roberts Street	5%	0%
Average	*15%*	*12%*
Central Region Gauges		
Waipapa @ Puketi	7%	6%
Waitangi @ Ohaeawai	-2%	-12%
Waima @ Kaikohe EDR	-12%	-12%
Opahi @ Cocksfoot	-21%	-17%
Average	*-7%*	*-9%*
Overall Average	*8%*	*5%*

Table 4 also shows the difference between the two estimates for the 100 yr 6 hour rainfall event. The comparison shows a smaller difference than the overall average. This is also shown in Figure 6, where the size of the difference between HIRDS V2 and the frequency analysis was greatest for six hour duration storms and 10 year ARI events and least for 24 hour 100 year ARI storms.

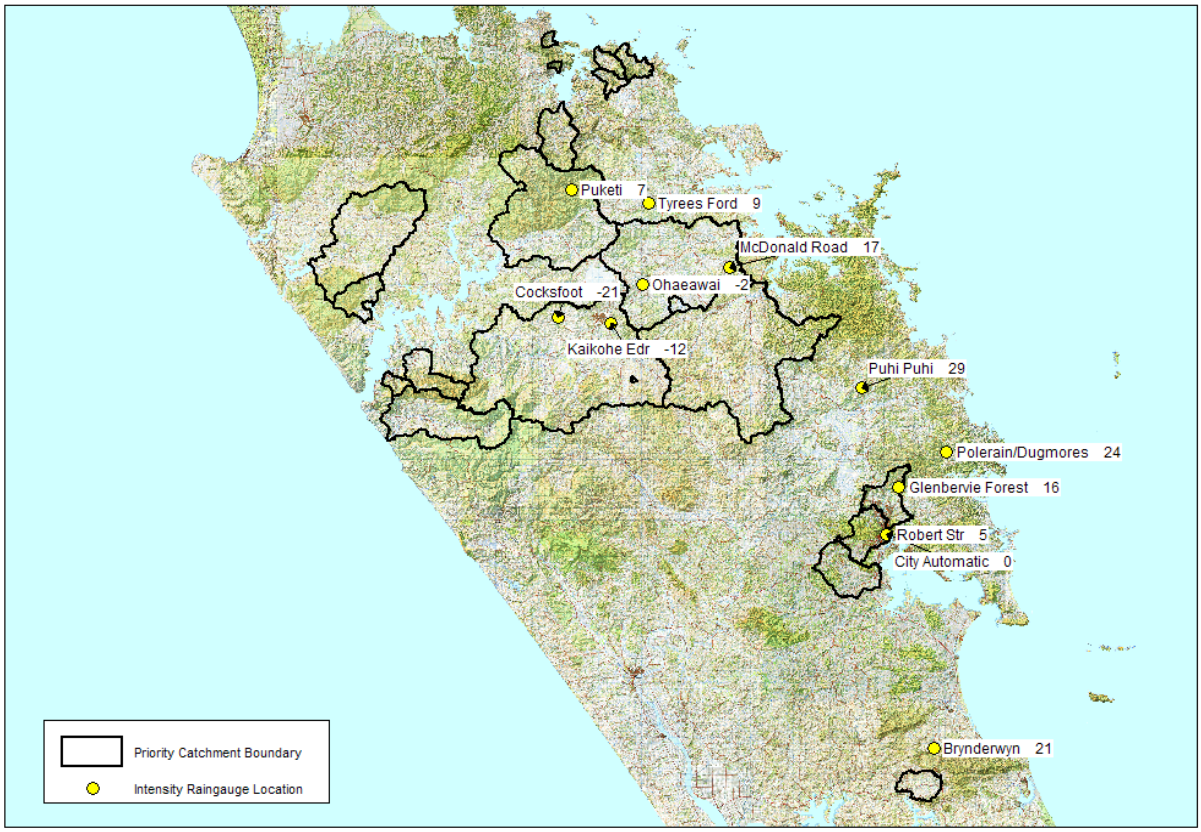


Figure 5 : Difference between Results of Frequency Analysis (Intensity Gauges) and HIRDS V2

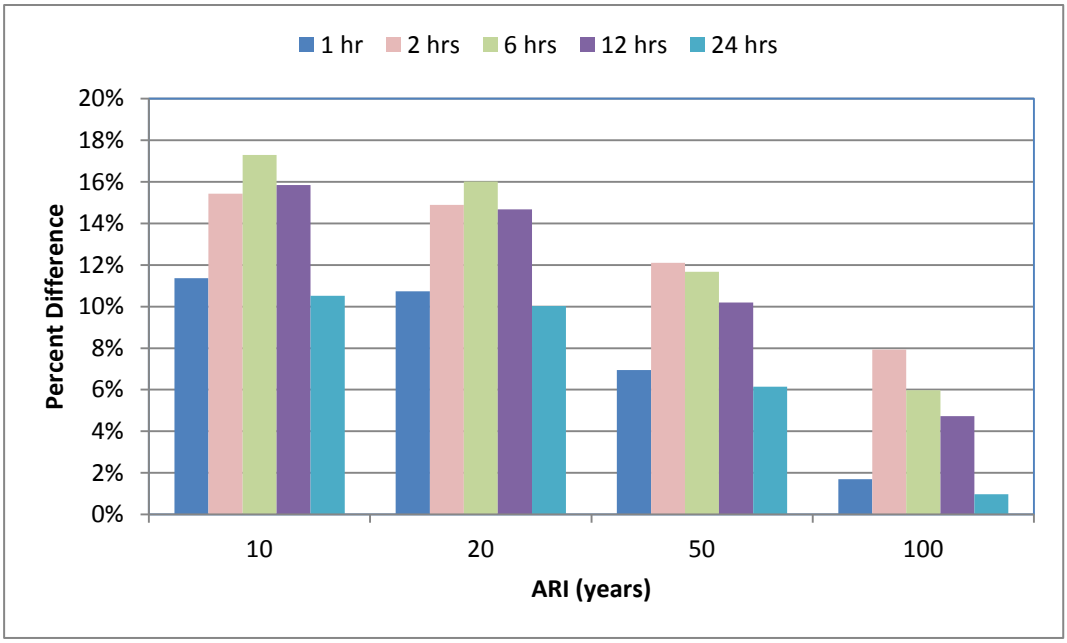


Figure 6: Comparison of Frequency Analysis (Intensity Gauges) and HIRDS V2

The increase in rainfall between 2001 and 2009 based on frequency analysis of 24 hour intensity data for 10, 20, 50 and 100 year ARI was also calculated. This was only possible for gauges that had sufficient data. The results in Table 5 show that for six east coast raingauges storm rainfall has increased by around 10% since the end of 2001.

Table 5: Increase in Frequency Analysis of Recorded Data Between 2001 and 2009

East Coast Gauges	% Increase Between 2001 and 2009
Maungaparerua at Tyrees Ford	23%
Whakapara @ Puhipuhi	8%
Hatea @ Glenbervie	-2%
Waihoihoi @ Brynderwyn	1%
Ngunguru @ Dugmores Rock	5%
Waitangi @ McDonald Road	23%
Whangarei @ Combined Auto	*Insufficient data to calculate*
Hatea @ Roberts Street	*Insufficient data to calculate*
Average	10%
Central Region Gauges	
Waipapa @ Puketi	*Insufficient data to calculate*
Waitangi @ Ohaeawai	*Insufficient data to calculate*
Waima @ Kaikohe EDR	20%
Opahi @ Cocksfoot	*Insufficient data to calculate*

2.3.2 Daily Raingauges

A comparison was also made between the results of the frequency analysis of daily recorded rainfall from 15 gauges and HIRDS V2. Results from the frequency analysis were generally less than HIRDS V2 depths by an average of 6%. This difference was similar for west, east and central regions as shown in Table 6. This result is the opposite to the comparison of HIRDS V2 and the frequency analysis of intensity data for the east coast. Results are plotted in Figure 7. The reason for the difference between the results of the daily and intensity rainfall analysis is unknown.

A comparison of data from 15 daily gauges up to the end of 2001 was also made to provide a direct comparison with HIRDS V2. 24 hour 100 year ARI depths for these gauges were 13% less than HIRDS V2.

An assessment of the change in daily rainfall between the end of 2001 and 2009 was made. For the 15 daily gauges there was an average increase in 24 hour 100 year ARI rainfall depths of 9% between the end of 2001 and 2009.

Table 6: Comparison of HIRDS V2 and Frequency Analysis of Daily Rainfall

Gauge Name	Frequency Analysis 100yr 24 hr (upto end of 2001) mm	HIRDS V2 100yr 24 hr (up to end of 2001) mm	Difference	Frequency Analysis 100yr 24 hr (full record up to 2009)	Difference (compared to HIRDS V2)	Change 2002 ---> 2009
East Coast						
Peach Orchard	296	340	-13%	382	12%	29%
Morgans	220	260	-15%	224	-14%	2%
Ferguson	238	280	-15%	248	-11%	4%
Hansens Orchards	310	260	19%	251	-3%	-19%
Cemetery Rd	158	250	-37%	177	-29%	12%
Redwood Orchard	195	240	-19%	192	-20%	-2%
Parua Bay	220	260	-15%	241	-7%	10%
Opua	196	220	-11%	203	-8%	4%
Whangae	209	230	-9%	302	31%	44%
Dawson	208	250	-17%	221	-12%	6%
Totara Place	188	232	-19%	201	-13%	7%
Average			-14%		-7%	9%
Central Region						
Waihou Valley	167	220	-24%	186	-15%	11%
Puketi Rd	270	260	4%	271	4%	0%
Average			-10%		-6%	6%
West Coast						
Waimamakau	205	210	-2%	223	6%	9%
Takahue Top	146	205	-29%	170	-17%	16%
Average			-16%		-5%	13%
Overall Average			-13%		-6%	9%

It is evident that rainfall intensities from HIRDS V2 are less than values calculated directly from recorded intensity data for the east coast. The difference is not completely surprising given the difference in methodology between the two estimates. HIRDS V2 uses a regionalised frequency analysis which smoothes contours of 24 hour 100 year rainfall and then applies average regional growth curves to produce depths for other durations and ARI's. This smoothing is likely to create the observed difference between HIRDS V2 and point estimates produced from the frequency analysis of site data. Also the inclusion of an additional 8 years of data since HIRDS V2 was released has increased the depth of design rainfall.

It is not clear why there is such a difference in results when comparing HIRDS V2 and daily data where generally HIRDS V2 provides greater design rainfall depths. It is clear however, that including an

additional 8 years of data from the end of 2001 to 2009 increases 24 hour 100 year ARI depths by around 9%.

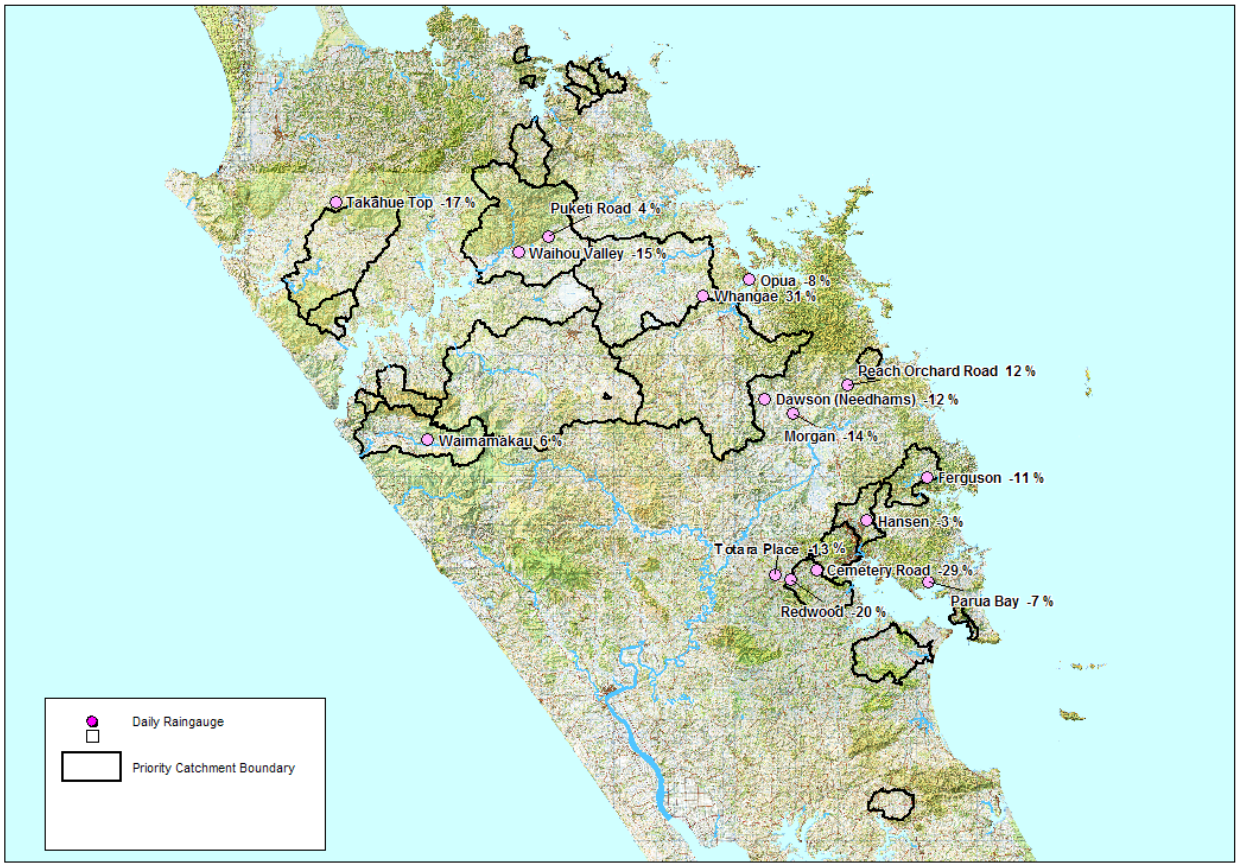


Figure 7: Difference between Results of Frequency Analysis (Daily Gauges) and HIRDS V2

In summary, the current version of HIRDS V2 provides a good representation of the spatial distribution of storm rainfall across the region. Rainfall depths from HIRDS V2 appear to produce rainfall depths approximately 15% lower than the results of frequency analysis on data recorded at long term intensity raingauges on the east coast (12% lower for the 100 year 6 hour event). There is also approximately a 10% increase in 24 hour 100 year ARI rainfall depths between 2001 and 2009 for both daily and intensity data. Although information is limited mainly to the east coast the results are considered sufficient evidence to apply a +10% correction factor to HIRDS V2 design rainfall estimates on the east coast and a 5% correction factor on the west coast and central regions.

The boundary for these two areas is shown in Figure 8.

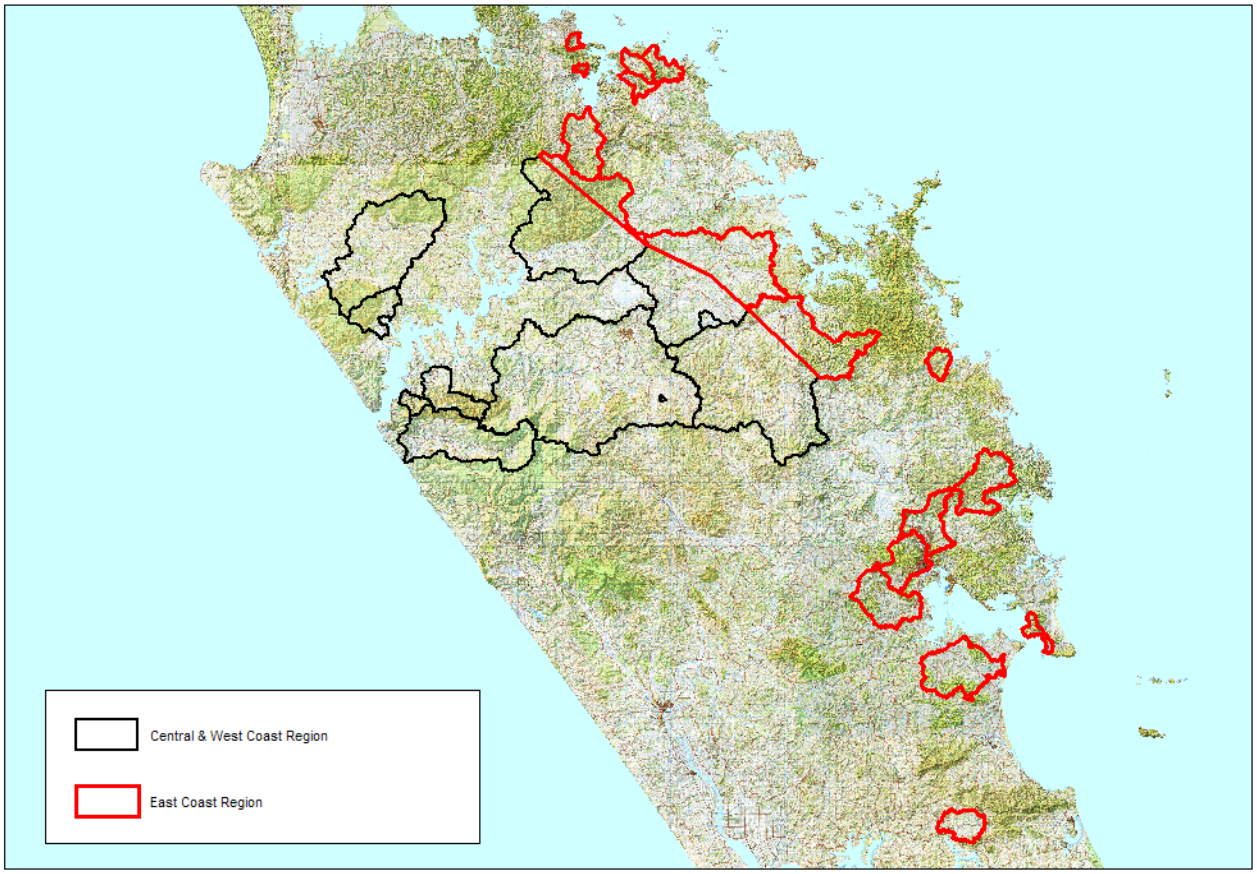


Figure 8: East Coast Boundary

2.4 HIRDS v3

NIWA are currently updating their HIRDS datasets and an alternative option is to use the HIRDS v 3 if it is made available in time for this project. A comparison between HIRDS v2, HIRDS v3 and at site frequency analysis was carried out after this report was completed. Results of the comparison are included as Appendix 3.

2.5 Rainfall Temporal Pattern

A standard temporal rainfall pattern was developed for the region based on the largest storms recorded at four intensity raingauges. The storms were extracted from the record at each gauge and normalised so that the peak rainfall depth and time to peak both equal 1.0 as shown in Figure 9. The normalised storms were then converted to cumulative curves and the average of the curves determined. (Figure 10). Compared to published standard temporal patterns (eg Huff 1967) the storms investigated peak relatively late.

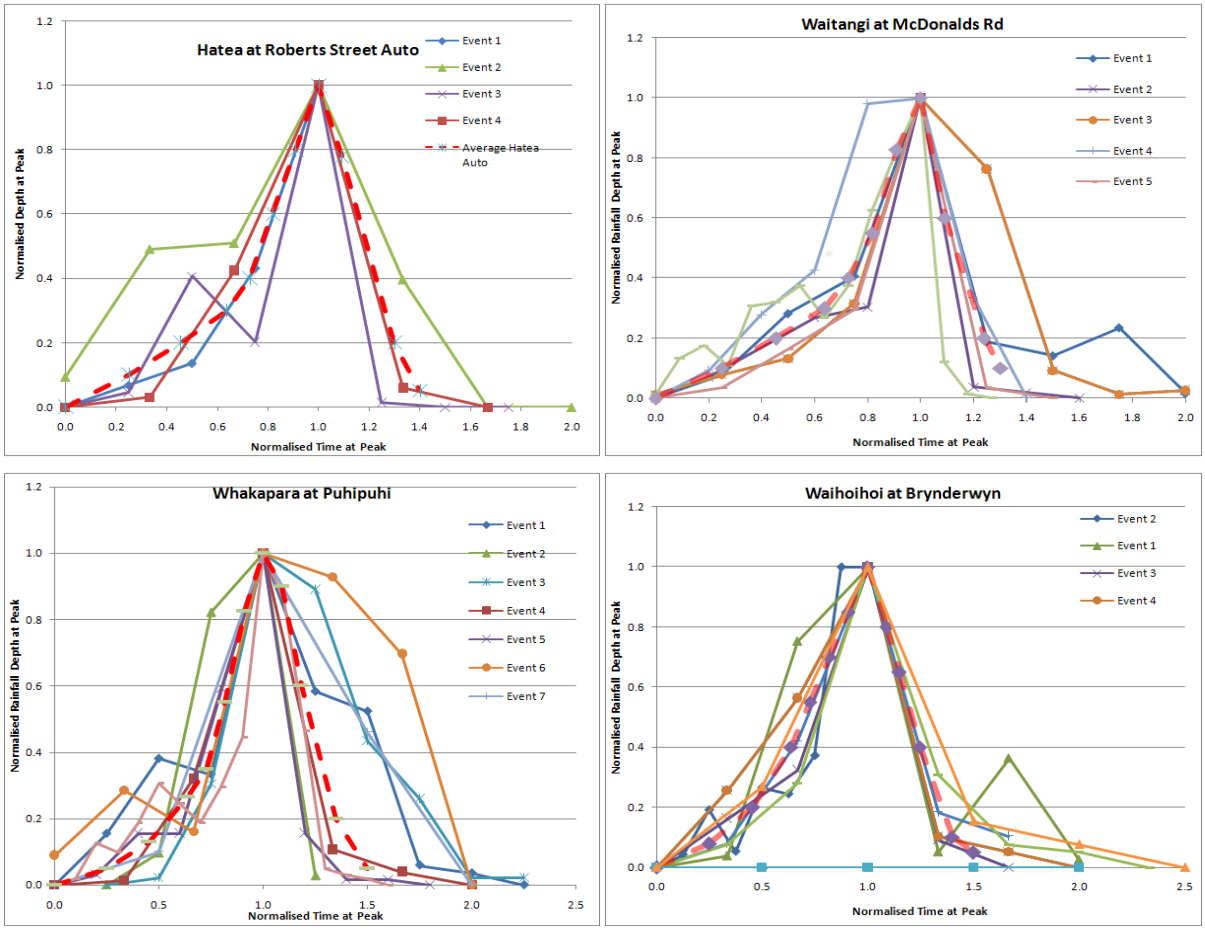


Figure 9: Development of Temporal Pattern

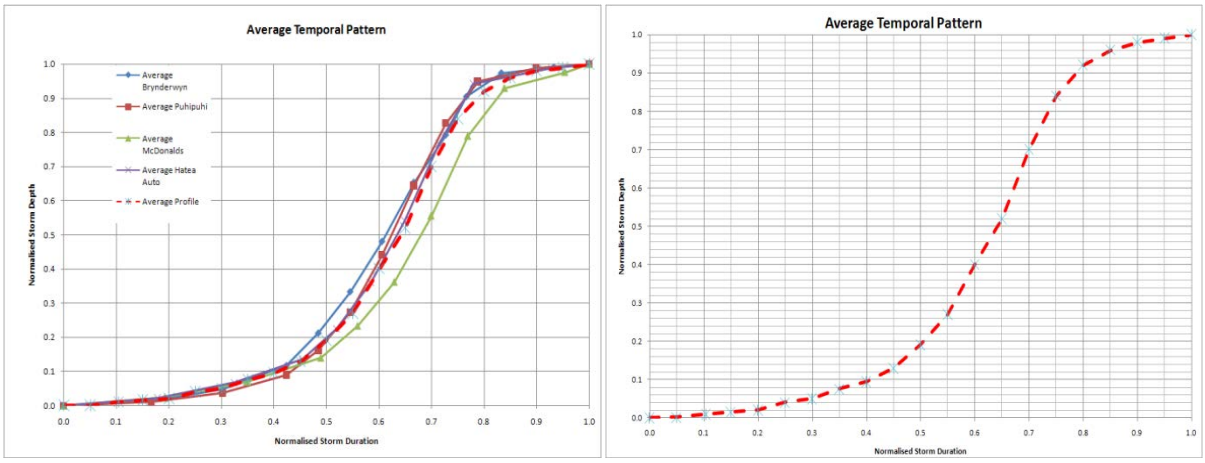


Figure 10: Average Temporal Pattern

2.6 Aerial Reduction Factor

Aerial reduction factors were applied to estimated rainfall depths based on Table 2.2 in Auckland Regional Councils Technical Publication 108.

2.7 Catchment Hyetographs

Catchment hyetographs were produced by extracting HIRDS V2 data for each required location, applying the correction factor and then applying the derived temporal pattern. See section on Hydraulic Modelling for a description of the locations where hyetographs were produced.

An example of the hyetograph produced in shown in Figure 11.

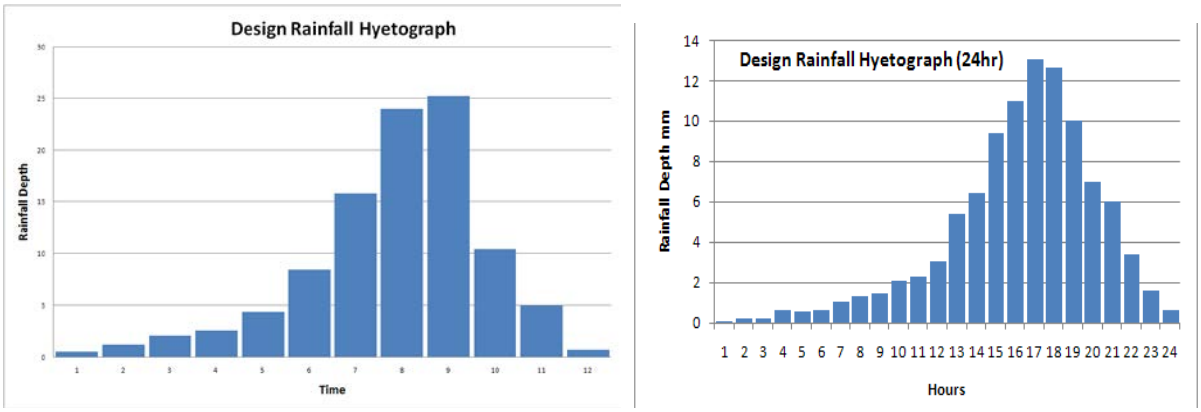


Figure 11: Design Hyetographs - 12 and 24 hour

3 Climate Change

3.1 Rainfall

The project brief specified that in addition to the 0.01 AEP flood, the 0.0005 AEP flood event should be modeled to account for climate change. The difference between 100 year and 200 year rainfall for the Glenbervie and Puhipuhi raingauges is 10%.

Following discussions with NRC it was decided to adopt an alternative approach to account for climate change as described in "Climate Change Effects and Impacts Assessment – A Guidance Manual for Local Government in New Zealand 2nd Edition" May 2008.

The results of climate change modeling presented in the 2008 guidance manual predict that between 1990 and 2040 there is likely to be an increase in temperature of around 0.9 degrees (range is 0.2 to 2.6). By 2090 temperature is predicted to rise by 2.1 degrees (range is 0.6 to 5.9). As a warmer atmosphere can hold more moisture (about 8% for every 1 degree increase in air temperature) there is a corresponding potential for more extreme high rainfalls.

The tables below show the percent increase in rainfall predicted for 2040 and 2090 for Northland.

Table 7: Projected % Increase in Extreme Rainfalls 2040, Middle Scenario, Northland

	ARI (years)			
Rainfall Duration (hours)	10	20	50	100
1	6.7	6.9	7.2	7.2
2	6.5	6.8	7.2	7.2
3	6.3	6.8	7.2	7.2
6	6.1	6.7	7.2	7.2
12	5.9	6.6	7.2	7.2
24	5.7	6.5	7.2	7.2

Table 8: Projected % Increase in Extreme Rainfalls 2090, Middle Scenario, Northland

	ARI (years)			
Rainfall Duration (hours)	10	20	50	100
1	15.5	16.2	16.8	16.8
2	15.1	16.0	16.8	16.8
3	14.7	15.8	16.8	16.8
6	14.3	15.5	16.8	16.8
12	13.7	15.3	16.8	16.8
24	13.2	15.1	16.8	16.8

As described above, the percentage increases in Table 6 and 7 are based on data up to 1990. Rainfall analysis carried out in this project was on data up to around 2090. The predicted increases can therefore be considered to be slightly conservative.

4 Uncertainty

Uncertainty associated with the measurement of rainfall used in this assessment is estimated to be in the order of +- 10%. There is also significant uncertainty associated with the results of the frequency analyses undertaken. This is primarily due to the relatively limited lengths of record available and lack of data to confirm the form of the frequency distribution used to extrapolate values. An appropriate allowance for uncertainty should therefore be made when using results reported in this document.

Appendix 1: Summary of all Intensity Raingauges

Site no	River Catchment	Site name	Map ref	Altitude m	Recorder	Telemetry	Records Begin	Records End
531313	Takahue	Te Rore	O 5:452692	250	OTA,Eco	Yes	11-Dec-03	
531415	Te Puhe	Mangakawaka Trig	O 4:531730	475	OTA,Aq	Yes	31-Jan-96	
351716	Kaeo	Kaeo	Q 4:829707	120	OTA,Eco	Yes	19-Sep-03	
533301	Rotokakahi	Kohe Rd	O 5:395542	36	OTA,M,Aq	Yes	19-Nov-98	
533817	Waitangi	Ohaeawai	P 5:901490	122	OTA,M,Aq	Yes	1-Jan-67	
534403	Hokianga Harbour	Opononi	O 6:462323	10	OTA,M,Eco	Yes	25-Sep-06	
534725	Waima	Kaikohe	P 5:831406	160	Rainlog,OTA		25-Jun-98	6-May-99
536613	Waima	Tutamoe	O 6:698156	500	OTA,Eco	Yes	25-Nov-03	
536812	Opouteke	Brookvale	P 6:891113	120	Aq,OTA	Yes	2-Nov-87	
536816	Mangakahia	Twin Bridges	P 6:879187	70	OTA,M,Aq	Yes	22-Apr-99	
543010	Waitangi	McDonalds Rd	P 5:045517	91	Rainlog,OTA	No	30-Apr-86	
545210	Wairau	Puhi Puhi	Q 6:261312	215	OTA,Aq	Yes	1-Nov-05	
546216	Wairua	Okarika	Q 6:163203	106	OTA,Rainlog	No	22-Feb-88	
546301	Hatea	Glenbervie Forest	Q 6:325152	100	OTA,Rainlog	No	31-Aug-47	
546416	Ngunguru	Polerain	Q 6:404213	150	OTA,Aq	Yes	28-Oct-87	
547336	Waiarohia	Whau Valley	Q 7:279099	60	FRev	na	2-Nov-79	16-Nov-87
547337	Raumanga	Base Hospital	Q 7:284062	29	FRev	na	20-Nov-87	26-Jul-88
547338	Hatea	Robert Str	Q 7:305076	10	OTA,Rainlog	na	16-Nov-89	25-Jun-04
547339	Waiarohia	NRC Water Street	Q 7:299076	15	OTA,Eco	Yes	25-Jun-04	
547340	Waiarohia	Kensington	Q 7:297092	40	OTA,Rainlog	Yes	19-Nov-06	
548215	Whangarei Harbour	Marsden Point	Q 7:453952	5	OTA,Star	Yes	20-Sep-06	
640436	Ahuroa	Brynderwyn	Q 8:382719	350	OTA, Aq	Yes	16-Feb-81	
641213	Paparoa	Maungaturoto	Q 8:323671	120	OTA,Eco	Yes	21-Apr-05	
641214	Paparoa	Taylors	Q 8:248650	80	OTA,Eco	Yes	20-Jul-05	
641511	Mangawhai Harbour	Tara	Q 8:477646	90	Rainlog,OTA	Yes	12-Dec-89	
643118	Kaipara Harbour	Pouto Point	Q 9:166370	20	OTA,Star	Yes	23-Nov-06	
644210	Lake Kanono	Kanono	Q 9:141366	61	Lam	na	21-Dec-78	26-Jun-79

Appendix 2: Intensity Raingauge Comparison of Frequency Analysis and HIRDS V2

Maungaparerua at Tyrees Ford

Frequency Analysis	Duration (hours)					to 2001
ARI	1	2	6	12	24	24
10	41	62	110	148	206	171
20	46	70	123	165	235	192
50	52	81	141	187	272	219
100	57	89	154	204	300	240
Total	196	302	528	704	1013	822
HIRDS V2	Duration (hours)					
ARI	1	2	6	12	24	
10	40	55	91	126	173	
20	46	64	105	145	199	
50	57	77	128	175	240	
100	66	90	149	204	279	
Total	209	287	473	649	891	

Difference between Freq Analysis & HIRDS V2
17%
14%
8%
2%

Difference between Freq Analysis & HIRDS V2	-6%	5%	12%	8%	14%

Whakapara @ Puhipuhi

Frequency Analysis	Duration (hours)					to 2001
ARI	1	2	6	12	24	24
10	61	91	147	215	275	256
20	71	106	168	247	314	292
50	84	125	195	287	368	339
100	93	140	215	318	408	374
Total	309	462	725	1067	1365	1261
HIRDS V2	Duration (hours)					
ARI	1	2	6	12	24	
10	50	68	112	153	210	
20	57	78	129	176	241	
50	69	94	155	212	291	
100	80	109	179	246	336	
Total	255	349	575	788	1078	

Difference between Freq Analysis & HIRDS V2
33%
33%
29%
24%

Difference between Freq Analysis & HIRDS V2	21%	32%	26%	35%	27%	17%

Hatea @ Glenbervie

Frequency Analysis	Duration (hours)					to 2001
ARI	1	2	6	12	24	24
10	48	66	125	173	227	226
20	55	76	145	199	262	264
50	64	88	170	234	307	314
100	70	98	189	259	340	351
Total	237	328	629	865	1136	1155
HIRDS V2	Duration (hours)					
ARI	1	2	6	12	24	
10	43	59	99	137	190	
20	50	69	115	159	219	
50	61	84	140	193	267	
100	71	98	164	226	311	
Total	225	310	518	715	987	

	Difference between Freq Analysis & HIRDS V2
	21%
	21%
	16%
	10%

Difference between Freq Analysis & HIRDS V2	6%	6%	22%	21%	15%	17%

Waihoihoi @ Brynderwyn

Frequency Analysis	Duration (hours)					to 2001
ARI	1	2	6	12	24	24
10	48	70	102	130	154	153
20	57	83	119	152	179	177
50	67	99	141	180	210	207
100	75	111	158	201	234	229
Total	247	363	520	663	777	766
HIRDS V2	Duration (hours)					
ARI	1	2	6	12	24	
10	36	49	78	105	142	
20	42	56	90	121	164	
50	51	68	109	147	199	
100	59	79	127	172	231	
Total	187	252	405	545	735	

	Difference between Freq Analysis & HIRDS V2
	23%
	25%
	21%
	17%

Difference between Freq Analysis & HIRDS V2	32%	44%	29%	22%	6%	4%

Waihoihoi @ Brynderwyn

Frequency Analysis	Duration (hours)					to 2001
ARI	1	2	6	12	24	24
10	48	70	102	130	154	153
20	57	83	119	152	179	177
50	67	99	141	180	210	207
100	75	111	158	201	234	229
Total	247	363	520	663	777	766
HIRDS V2	Duration (hours)					
ARI	1	2	6	12	24	
10	36	49	78	105	142	
20	42	56	90	121	164	
50	51	68	109	147	199	
100	59	79	127	172	231	
Total	187	252	405	545	735	

Difference between Freq Analysis & HIRDS V2
23%
25%
21%
17%

Difference between Freq Analysis & HIRDS V2						
	32%	44%	29%	22%	6%	4%

Waihoihoi @ Brynderwyn

Frequency Analysis	Duration (hours)					to 2001
ARI	1	2	6	12	24	24
10	48	70	102	130	154	153
20	57	83	119	152	179	177
50	67	99	141	180	210	207
100	75	111	158	201	234	229
Total	247	363	520	663	777	766
HIRDS V2	Duration (hours)					
ARI	1	2	6	12	24	
10	36	49	78	105	142	
20	42	56	90	121	164	
50	51	68	109	147	199	
100	59	79	127	172	231	
Total	187	252	405	545	735	

Difference between Freq Analysis & HIRDS V2
23%
25%
21%
17%

Difference between Freq Analysis & HIRDS V2						
	32%	44%	29%	22%	6%	4%

Ngunguru @ Dugmores Rock

Frequency Analysis	Duration (hours)					to 2001
ARI	1	2	6	12	24	24
10	52	74	120	170	244	229
20	60	90	137	194	281	267
50	70	114	159	225	330	316
100	78	136	176	249	366	353
Total	260	414	592	838	1221	1165
HIRDS V2	Duration (hours)					
ARI	1	2	6	12	24	Difference between Freq Analysis & HIRDS V2
10	44	59	98	133	182	28%
20	50	69	113	154	210	28%
50	61	84	137	187	255	24%
100	72	98	160	218	297	19%
Total	227	310	507	691	943	

Difference between Freq Analysis & HIRDS V2	15%	34%	17%	21%	29%	24%

Waitangi @ McDonald Road

Frequency Analysis	Duration (hours)					to 2001
ARI	1	2	6	12	24	24
10	42	60	104	142	178	148
20	47	68	120	163	205	168
50	54	79	140	191	240	193
100	59	88	155	212	266	212
Total	202	295	519	708	889	721
HIRDS V2	Duration (hours)					
ARI	1	2	6	12	24	Difference between Freq Analysis & HIRDS V2
10	41	54	83	110	146	21%
20	47	62	96	127	168	21%
50	56	74	116	153	203	17%
100	65	86	134	178	235	12%
Total	208	275	429	568	751	

Difference between Freq Analysis & HIRDS V2	-3%	7%	21%	25%	18%	-4%

Whangarei @ Combined Auto 1988 to 2009

Frequency Analysis	Duration (hours)					to 2001
ARI	1	2	6	12	24	24
10	37	54	99	128	154	
20	43	63	114	150	178	
50	50	73	134	178	210	
100	55	81	149	201	233	
Total	185	271	496	657	775	
HIRDS V2	Duration (hours)					
ARI	1	2	6	12	24	
10	39	54	87	118	161	
20	46	62	101	136	185	
50	56	76	123	166	224	
100	66	89	143	193	261	
Total	207	280	453	614	831	

Difference between Freq Analysis & HIRDS V2
3%
3%
0%
-4%

Difference between Freq Analysis & HIRDS V2	-11%	-3%	9%	7%	-7%

Waipapa @ Puketi Ends in 1994

Frequency Analysis	Duration (hours)					to 2001
ARI	1	2	6	12	24	24
10	54	73	110	141	183	
20	63	83	125	159	205	
50	75	98	145	181	233	
100	83	109	160	198	253	
Total	275	363	540	679	874	
HIRDS V2	Duration (hours)					
ARI	1	2	6	12	24	
10	40	56	93	129	178	
20	47	64	107	148	205	
50	57	78	130	179	246	
100	66	91	151	207	285	
Total	209	289	481	663	914	

Difference between Freq Analysis & HIRDS V2
13%
11%
6%
0%

Difference between Freq Analysis & HIRDS V2	31%	26%	12%	2%	-4%

Waitangi @ Ohaeawai 1998 to 2009

Frequency Analysis	Duration (hours)					to 2001
ARI	1	2	6	12	24	24
10	40	53	94	130	180	
20	45	60	104	145	203	
50	52	68	116	163	234	
100	56	74	126	177	256	
Total	193	255	440	615	873	
HIRDS V2	Duration (hours)					
ARI	1	2	6	12	24	
10	40	54	89	122	166	
20	45	62	102	140	191	
50	55	75	123	169	231	
100	64	87	143	196	268	
Total	203	278	457	625	855	

Difference between Freq Analysis & HIRDS V2
6%
3%
-3%
-9%

Difference between Freq Analysis & HIRDS V2	-5%	-8%	-4%	-2%	2%	-100%

Hatea @ Roberts Street 1989 to 2004

Frequency Analysis	Duration (hours)					to 2001
ARI	1	2	6	12	24	24
10	40	53	88	124	178	
20	48	64	105	145	207	
50	60	79	127	173	245	
100	69	90	143	194	273	
Total	217	286	463	636	903	0
HIRDS V2	Duration (hours)					
ARI	1	2	6	12	24	
10	39	54	87	118	161	
20	46	62	101	136	185	
50	56	76	123	166	224	
100	66	89	143	193	261	
Total	207	280	453	614	831	

Difference between Freq Analysis & HIRDS V2
5%
7%
6%
2%

Difference between Freq Analysis & HIRDS V2	5%	2%	2%	4%	9%	-100%

Opahi @ Cocksfoot **11 Jul 1985 to 1994**

Frequency Analysis	Duration (hours)					to 2001
	1	2	6	12	24	**24**
10	40	47	72	82	101	
20	46	54	82	92	113	
50	53	62	95	105	129	
100	59	69	104	114	140	
Total	198	232	353	393	483	
HIRDS V2	Duration (hours)					
ARI	1	2	6	12	24	
10	36	48	78	105	142	
20	41	55	89	121	163	
50	49	67	108	146	197	
100	57	78	125	169	229	
Total	183	248	400	541	731	

Difference between Freq Analysis & HIRDS V2
-16%
-18%
-22%
-26%

Difference between Freq Analysis & HIRDS V2						
	8%	-6%	-12%	-27%	-34%	-100%

Waima @ Kaikohe EDR 1985 to 2009 with 4.75 year gap from 1 Apr 2002

Frequency Analysis	Duration (hours)					to 2001
	1	2	6	12	24	24
10	33	51	88	117	144	123
20	37	57	98	131	162	136
50	43	65	112	149	185	152
100	47	72	122	163	202	165
Total	160	245	420	560	693	576
HIRDS V2	Duration (hours)					
ARI	1	2	6	12	24	
10	38	52	86	119	163	
20	44	60	99	136	187	
50	53	73	120	165	226	
100	61	84	139	191	262	
Total	197	270	445	611	838	

Difference between Freq Analysis & HIRDS V2
-5%
-8%
-13%
-18%

Difference between Freq Analysis & HIRDS V2						
	-19%	-9%	-6%	-8%	-17%	-31%

Appendix 3: Comparison of HIRDS v2 and HIRDS v3 with at site Rainfall Frequency Analysis

Drafted by MWH and updated by NIWA following the release of HIRDS v3.

The following analysis was undertaken on a selection of long term rainfall records located in or near catchments being studied for the Priority Rivers Project in Northland.

Frequency analysis of intensity data to 2009 from east coast gauges gave average depths 3% greater than HIRDSv3. This compares with 15% for HIRDSv2. For all twelve intensity gauges assessed the difference has dropped from 8% to -1%. For the 6hr 100 year event for all intensity gauges the difference has dropped from HIRDS v2 5% to HIRDS ver3 -1%. See Revised Table 1.

For the fifteen daily gauges assessed, HIRDS v3 gave depths 20% greater than the frequency analysis (to 2009) for the 24 hr 100 year ARI event. This compares with 6% greater depths for HIRDS v2. As was found previously, these results are relatively consistent for east coast, central and west coast daily gauges. See Revised Table 2.

HIRDS v3 gave depths on average 9% greater than HIRDS v2 for intensity gauges (all durations and ARI's). HIRDS v3 gave depths 18% greater than v2 for daily gauges (24 hr 100 ARI).

It is concluded than HIRDS v3 (09) has reduced the observed difference between rainfall depths calculated from frequency analysis and HIRDS v2 (for automated gauges). HIRDS v3 gives rainfall depths greater than v2 roughly equivalent to the estimated increase in storm rainfall between 2002 and 2009 (10% for intensity and 9% for daily gauges). Whilst HIRDS v3 may appear to give conservative estimates in relation to the analysis of daily rain gauge data, it correlates well with frequency analysis undertaken for automatic gauges. Further assessment and comparison is recommended for other long term records in Northland but it seems reasonable at this stage to use HIRDS v3 without correction for all catchments in the Priority Rivers Flood Risk Reduction Project.

Revised Table 1 Intensity Raingauges

	Difference FA*/ HIRDSv2	Difference FA/ draft HIRDSv3	Difference FA/ HIRDSv3-09	Difference draft HIRDSv3/ v2	Difference HIRDS v3-09/ v2	Difference FA/ HIRDSv2	Difference FA/ draft HIRDSv3	Difference FA/ HIRDSv3-09
East Coast Gauges	(All durations and ARI)**	(All durations and ARI)	(All durations and ARI)	(All durations and ARI)	(All durations and ARI	(100 yr 6 hr event)	(100 yr 6 hr event)	(100 yr 6 hr event)
Maungaparerua at Tyrees Ford	9%	0%	-3%	9%	10%	4%	-2%	-5%
Whakapara @ Puhipuhi	29%	14%	12%	13%	14%	20%	8%	3%
Hatea @ Glenbervie	16%	10%	4%	5%	9%	15%	9%	5%
Waihoihoi @ Brynderwyn	21%	10%	7%	10%	19%	24%	12%	0%
Ngunguru @ Dugmores Rock	24%	12%	5%	11%	17%	10%	4%	-6%
Waitangi @ McDonald Road	17%	16%	4%	1%	9%	16%	17%	5%
Whangarei @ Combined Auto	0%	-2%	-4%	2%	4%	4%	3%	1%
Hatea @ Roberts Street	5%	3%	1%	2%	4%	0%	-1%	-3%
Average	15%	8%	3%	6%	11%	12%	6%	0%
Central Gauges								
Waipapa @ Puketi	7%	-5%	4%	13%	9%	6%	-4%	-3%
Waitangi @ Ohaeawai	-2%	-9%	-11%	8%	8%	-12%	-18%	-18%
Waima @ Kaikohe EDR	-12%	-14%	-13%	3%	1%	-12%	-11%	-13%
Opahi @ Cocksfoot	-21%	-21%	17%	0%	2%	-17%	-18%	-18%
Average	-7%	-12%	-9%	6%	5%	-9%	-13%	-13%
Overall Average	8%	2%	-1%	6%	9%	5%	0%	-1%

*Frequency Analysis

** 1, 2, 6,12, 24hr durations, 10, 20, 50 and 100yr ARI

Revised Table 2 Daily Raingauges

Site Number	Gauge Name	Freq Analysis 100yr 24 hr (up to end of 2001) mm	HIRDSv2 100yr 24 hr (upto end of 2001) mm	Difference (FA 02/ HIRDSv2)	HIRDSv3 100yr 24 hr (mm)	HIRDSv3 100yr 24 hr up to 2009 (mm)	Freq Analysis 100yr 24 hr (full record up to 2009)	Difference (FA to 09/ HIRDSv2)	Difference (FA 2009 / 2002)	Difference (FA 09/ HIRDSv3)	Difference (FA 09)/ HIRDS v3 - 09	Difference HIRDS v3/v2	Difference HIRDS v3 -09/v2
	East Coast												
544311	Peach Orchard	296	340	-13%	397	431	382	12%	29%	-4%	-12%	17%	27%
545213	Morgans	220	260	-15%	324	335	224	-14%	2%	-31%	-33%	25%	29%
546412	Ferguson	238	280	-15%	331	361	248	-11%	4%	-25%	-31%	18%	29%
546315	Hansens Orchards	310	260	19%	311	325	251	-3%	-19%	-19%	-23%	20%	25%
547219	Cemetery Rd	158	250	-37%	249	252	177	-29%	12%	-29%	-30%	0%	0%
547223	Redwood Orchard	195	240	-19%	237	237	192	-20%	-2%	-19%	-19%	-1%	-1%
547411	Parua Bay	220	260	-15%	289	311	241	-7%	10%	-17%	-22%	11%	19%
543110	Opua	196	220	-11%	249	296	203	-8%	4%	-18%	-31%	13%	34%
543012	Whangae	209	230	-9%	250	296	302	31%	44%	21%	2%	9%	29%
545111	Dawson	208	250	-17%	287	292	221	-12%	6%	-23%	-24%	15%	17%
547214	Totara Place	188	232	-19%	232	231	201	-13%	7%	-13%	-13%	0%	-1%
	Average			**-14%**				**-7%**	**9%**	**-16%**	**-21%**	**11%**	**19%**
	Central Region												
532611	Waihou Valley	167	220	-24%	257	258	186	-15%	11%	-28%	-18%	17%	17%
532710	Puketi Rd	270	260	4%	309	313	271	4%	0%	-12%	-13%	19%	20%
	Average			**-10%**				**-6%**	**6%**	**-20%**	**-15%**	**18%**	**18%**
	West Coast												
535512	Waimamakau	205	210	-2%	229	221	223	6%	9%	-3%	1%	9%	5%
532311	Takahue Top	146	205	-29%	285	248	170	-17%	16%	-40%	-31%	39%	21%
	Average			**-16%**				**-5%**	**13%**	**-21%**	**-16%**	**24%**	**13%**
				-13%				***-6%***	***9%***	***-17%***	***-20%***	***14%***	**18%**