Northland floods: 28-29 March and 9-10 July 2007

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Executive Summary

Severe storms over Northland in March and July 2007 resulted from quite similar weather patterns: a depression moving southeast from the north Tasman Sea towards the North Island coast and encountering a blocking high pressure system to the east of the country.

In the March storm, extremely heavy rainfalls occurred over the eastern side of Northland: in some cases two-day totals exceeded 400 mm and were in excess of 1/100 AEP estimates.

Record high flood flows occurred in rivers on the eastern side of Northland. A number of the peak flows exceeded both 1/50 and 1/100 AEP estimates.

The July storm had a few two-day totals exceeding 300 mm, but was more widely distributed with much of the region receiving more than 100 mm in two days. Although runoff rates were quite high because of prevailing seasonally high soil moisture levels, only two rivers of those analysed had record high flood flows and two of the peaks exceeded 1/50 AEP estimates.

The March and July two-day storm totals for Kaeo automatic raingauge were 323 mm and 289 mm respectively. Rainfall rates during these storms both exceed the Kaeo 1/100 AEP estimates.

Decadal-scale variations in El Niño Southern Oscillation patterns suggest that in Northland the period 1978-1999 may have been relatively quiescent and that the post-1999 years may be experiencing severe weather and floods that are more similar to patterns experienced in 1947-1977. This topic may be worth exploring further.

1. Introduction

Following severe floods in Northland in March and July 2007, Mr Dale Hansen of the Northland Regional Council requested NIWA to:

1: Collate and review data for specified automatic raingauges and flow recorders.

2: Undertake a comprehensive analysis of rainfall and flow data for each site to establish conclusive return periods for the 10 July 2007 event and a comparative evaluation to the 29 March 2007 event. Rainfall events should be based on 6, 12, 24 and 48 hour durations.

3: Assess the antecedent rainfall and soil moisture characteristics prior to both events.

4: Assess the limitations of the data (i.e. degree of accuracy).

5: Provide a report.

Fourteen automatic raingauges and 15 flow recorders were specified for detailed analysis. However, to gain comprehensive pictures of the storms, data from all the Northland region were assembled.

The frequency of storms and floods can be described using several alternatives. In this report, probability of an event of a particular magnitude (characterised by storm rainfall depth or peak flood size) being exceeded in any year is used: this is the Annual Exceedence Probability (AEP).

The terms “return period” and “average recurrence interval” are the reciprocal of AEP. A flood with AEP of 1/T has a return period of “T”: the return period T is the average interval between years with events exceeding the 1/T AEP estimate. The word “average” is important. As the experience of Southland in the period 1978-1980 shows, large floods can group together over a few years, and the term “return period”, which is sometimes taken to imply that large floods should be nearly equally spaced at long intervals apart, is unhelpful in this regard.

In this report, storm rainfalls are compared with 1/10, 1/50 and 1/100 AEP estimates. This enables the areal extent of storm severity to be assessed.

2. Storm descriptions

The synoptic chart for 0 h on 28 March (Figure 1) shows a large eastwards moving anticyclone east of the South Island and a northeast airflow covering New Zealand and the eastern Tasman Sea. A shallow trough of low pressure covered the central and northern Tasman Sea, and on the following day (29 March) the main centre of the trough complex was centred west of Taranaki, while a strong moist northerly flow covered the North Island between the two systems. As the anticyclone continued to move northeastwards away from New Zealand on the 30th March, the shallow trough/depression complex moved across the North Island during the day accompanied by rain and showers, while another trough of low pressure moved into the south Tasman Sea from the southern oceans.

The synoptic charts for the July storm (Figure 2) show a deepening depression on 9 July lying over the north Tasman Sea and moving southeastwards towards northern New Zealand. At the same time an intense and slow moving anticyclone covered the south Tasman Sea and extended a slowly weakening ridge of high pressure over and to the east of New Zealand. Between these two systems a strengthening humid northeasterly flow was spreading onto the North Island. By 10 July the deep depression lay just north of the North Island with its main centre northwest of Cape Reinga. Gale force northeasterlies on the depression's southern side covered the northern half of the North Island. Over the following two days, the deep depression progressed slowly in a general easterly direction, with gale force winds gradually weakening and turning southeast.

The common features of these two events is the active depression moving southwest from the north Tasman Sea to lie to the west of the North Island, and being squeezed against a blocking high pressure system to the east of the country, with the result that moist subtropical air masses from the northeast are drawn south over the Northland region.

3. Storm rainfall

3.1. Data available

Raingauge networks in Northland are operated by the NRC, NIWA and the Meteorological Service of New Zealand Ltd (MetService). The NRC and NIWA networks comprise both manual (daily read) gauges and recording gauges whereas the MetService gauges, which are all recording, are components of automatic weather stations (AWSs). Most of the NIWA recording gauges are part of Electronic Weather Stations (EWSs). The manual gauges are read at 0900 h NZ Daylight Time by

observers who enter daily observations onto monthly sheets that are sent to the recording authority. A local variation is that although the NRC daily rainfalls are read at 0900 h NZDT as described above, the data are archived at 2400 h. Thus for example, the daily total read at 0900 h on 30 March is archived at 2400 h on 29 March. The recording (or automatic) gauges typically use tipping buckets to record each 0.2 or 0.5 mm increments of rain, and supply rainfall totals for any specified time increment. The AWS and EWS rain data are archived as hourly totals. All the NIWA data (rainfall and streamflow) and the MetService and NRC automatic gauge data used in this study are archived to NZ standard time.

The locations of 96 Northland raingauges for which data were available are listed in Table 1.

3.2. Data checks and storm patterns

To check the storm data and also to provide detail of the storm patterns, cumulative plots for the automatic and daily-read raingauges were prepared.

For the March storm, Figures 3 and 4 show the cumulative rainfalls recorded at the MetService and NIWA, and NRC automatic raingauges respectively. Figures 5 and 6 show cumulative daily rainfalls for the NIWA and NRC daily raingauges respectively that received higher rainfalls.

For the July storm, Figures 7 and 8 show the cumulative rainfalls recorded at the MetService and NIWA, and NRC automatic gauges. Figures 9 and 10 show cumulative daily rainfalls for the NIWA and NRC daily raingauges respectively that received higher rainfalls.

In preparing the figures, various minor timing corrections to some of the daily data were made. Also, for the March storm, the gauge number 544311 (Peach Orchard Rd) had a storm total of 730 mm. This was easily the maximum recorded for this storm at any gauge, and investigation by the NRC revealed that part of this total was not actually recorded, but was estimated based on readings for the earlier part of the storm. Since there were other nearby raingauges with reliable records, this gauge was not used for the March storm.

3.3. Mapping of storm depths

Figures 11 and 12 map the rainfall totals for all the raingauges for the two-day periods ending at 0900 h on 30 March and 11 July respectively. The map contours are

Table 1: List of raingauges and NZ Map Grid coordinates for their locations.

Site No.	Location	Easting	Northing	Authority	Type
424602	Cape Reinga AWS	2481900	6752500	MetService	Auto
425902	Paua Blk Parengarenga	2501100	6736900	NIWA	Manual
439201	Waiharara	2528700	6694800	NIWA	Manual
439202	Waiharara	2530300	6696300	NIWA	Manual
530204	Aupouri Forest HQ	2528900	6687900	NRC	Manual
530205	Kaitaia (Wiessing)	2534200	6681700	NRC	Manual
530206	Kaitaia Aero EWS	2537000	6681500	NIWA	Auto
530701	Kaeo	2578400	6682600	NIWA	Manual
530810	Matauri Bay (NZ China Clays)	2592634	6681365	NRC	Manual
531201	Kaitaia	2534500	6676600	NIWA	Manual
531205	Kaitaia Observatory	2534800	6674200	NIWA	Manual
531207	Kaitaia EWS	2534800	6674200	NIWA	Auto
531313	Te Rore	2544722	6669178	NRC	Auto
531411	Victoria Valley (Kitchen)	2548200	6672900	NRC	Manual
531414	Peria (Banks)	2556828	6679316	NRC	Manual
531415	Mangakawaka Trig	2552539	6672633	NRC	Auto
531512	Coopers Beach	2558213	6690049	NRC	Manual
531513	Mangonui	2559800	6689700	NRC	Manual
531711	Kaeo (Paitu)	2583500	6675500	NRC	Manual
531717	Kaeo (Bramleys)	2582950	6670841	NRC	Auto
531901	Kerikeri EWS	2595200	6668400	NIWA	Auto
531911	Kerikeri	2597300	6666900	NRC	Manual
532311	Takahue Top (Schou)	2544000	6665300	NRC	Manual
532611	Waihou Valley (Graham)	2574200	6656900	NRC	Manual
532710	Puketi Rd (Candy)	2579200	6659600	NRC	Manual
532821	Maungaparerua at Tyrees Ford	2591271	6662437	NIWA	Auto
532903	Kerikeri Aero 2	2594000	6659500	NIWA	Manual
533201	Puhata	2531800	6655700	NIWA	Manual
533817	Ohaeawai	2590100	6649000	NRC	Auto
534503	Rawene 2	2557900	6643300	NIWA	Manual
534726	Te Opou Stm (Punakitere)	2587454	6631251	NRC	Manual
534807	Kaikohe EDR	2585400	6641800	NIWA	Auto
535412	Waiotemarama (Tooremburg)	2550550	6629628	NRC	Manual
535413	Whirinaki (King)	2551800	6634800	NRC	Manual
535512	Wekaweka Russell	2559223	6625979	NRC	Manual
536501	Waipoua Forest	2561200	6616600	NIWA	Manual
536613	Tutamoe	2569648	6615272	NRC	Auto
536812	Opouteke Brookvale	2589100	6611300	NRC	Auto
536816	Twin Bridges	2587766	6618749	NRC	Auto
537614	Whatoro (Coates)	2572155	6606020	NRC	Manual
537815	Tangowahine	2586500	6606700	NRC	Manual
537901	Parakao	2596900	6609300	NIWA	Manual
538801	Mamaranui	2582900	6593000	NIWA	Manual
539710	Baylys Beach (Andrews)	2578100	6583100	NRC	Manual
539807	Dargaville 2 EWS	2587600	6585200	NIWA	Auto
539813	Dargaville (Hokianga Road)	2588036	6585202	NRC	Manual
541001	Purerua AWS	2603400	6674300	MetService	Auto

Site No.	Location	Easting	Northing	Authority	Type
542101	Russell	2612700	6659000	NIWA	Manual
543001	Kawakawa Council	2607200	6646200	NIWA	Manual
543010	McDonalds Rd	2604509	6651733	NRC	Auto
543012	Whangae (Waitangi)	2604700	6649700	NRC	Manual
543110	Opua	2612300	6652400	NRC	Manual
543311	Oakura (Murphy)	2632800	6644700	NRC	Manual
543312	Oakura Bay (Te Kapua St)	2632800	6644700	NRC	Auto
544311	Kaimamaku (Peach Orchard Rd)	2628600	6635100	NRC	Manual
545013	Okaroro	2604054	6630730	NRC	Manual
545111	Waiotu (Dawson)	2615000	6632800	NRC	Manual
545201	Puhipuhi auto	2626700	6632300	NRC	Auto
545213	Hukerenui (Morgans)	2619700	6630300	NRC	Manual
545311	Kirikiritoki, Maureens	2635290	6625233	NRC	Manual
545312	Kaimamaku, Dandelion	2628600	6632400	NRC	Manual
545501	Matapouri	2647300	6625200	NIWA	Manual
546212	Jordan Valley Rd (Smith)	2621700	6621400	NRC	Manual
546216	Okarika	2616254	6620306	NRC	Auto
546218	Wairua	2617729	6616274	NRC	Manual
546220	Crane Rd (Money)	2627755	6616247	NRC	Manual
546301	Glenbervie Forest	2632500	6615200	NRC	Auto
546316	Glenbervie (Batt)	2637100	6615800	NRC	Manual
546412	Kaiatea (Ferguson)	2641900	6619800	NRC	Manual
546416	Polerain	2640430	6621278	NRC	Auto
546512	Whangaumu Bay (Lambly)	2649200	6617300	NRC	Manual
547010	Parakao (Ware)	2601300	6609400	NRC	Manual
547214	Raumanga (Totara Place)	2627920	6605548	NRC	Manual
547219	Mokupara (Cemetery Rd)	2623500	6604600	NRC	Manual
547223	Maungatapere, Redwood Orchard	2619200	6602900	NRC	Manual
547224	Otaika Valley (McIntosh)	2626529	6600580	NRC	Manual
547225	Whatatiri, Coopers	2616521	6603080	NRC	Manual
547307	Whangarei Aero AWS	2634000	6602800	MetService	Auto
547339	NRC Water St	2629899	6607524	NRC	Auto
547340	Kensington	2629607	6609207	NRC	Auto
547341	Limestone Island, Whangarei Harbour	2633795	6600792	NRC	Manual
547411	Parua Bay, Whangarei Harbour	2642100	6602500	NRC	Manual
548213	Ruakaka (Fosters)	2642872	6589987	NRC	Manual
548214	Mangapai (Palmer)	2625421	6596208	NRC	Manual
548215	Marsden Point	2645291	6594740	NRC	Auto
549010	Manganui (Moneymusk)	2604900	6578000	NRC	Manual
630901	Arapohue	2595400	6578000	NIWA	Manual
640436	Brynderwyn	2638225	6571943	NRC	Auto
640501	Waipu Cove	2646400	6573200	NIWA	Manual
641211	Matakohe	2615200	6566500	NRC	Manual
641215	Pahi (Stubbs)	2620842	6559823	NRC	Manual
641310	Maungaturoto (Nthld Dairy Co)	2634300	6565500	NRC	Manual
642802	Leigh 2	2671900	6546200	NIWA	Auto
643118	Kaipara Harbour (Pouto Pt)	2616556	6536998	NRC	Auto
644604	Warkworth EWS	2660000	6528500	NIWA	Auto
646901	Tiri Tiri Lighthouse	2680200	6508800	NIWA	Manual

generated using an inverse distance weighting scheme. Maps of one-day totals for the storms are not included because the automatic gauge data (Figures 3, 4, 9 and 10) show that the storm totals are spread across the two-day periods.

3.4. Storm frequency analyses

Storm rainfall totals for durations of 6, 12, 24 and 48 hours were extracted for 16 automatic gauges, including those flagged by the NRC as of particular interest, and also the NIWA gauges at Mangaparerua and Kerikeri EWS and the MetService gauge Whangarei Aero AWS that received high totals. The results are presented as a series of intensity-frequency-duration plots in Figures 13 and 14.

Maps showing the areas where 1/10 and 1/50 AEP 48 h rainfalls were exceeded are presented in Figures 15 and 16. The maps were prepared using the automatic gauge maxima over 48 hour intervals and the daily 0900 h to 0900 h totals for the daily-read gauges. To allow for the fact that the manual gauge two-day totals are maxima over a fixed time partition, they were multiplied by a factor of 1.07 (Tomlinson, 1980).

4. Flood data

Streamflow data for the sites listed in Table 2 were examined.

As rating curves, used to transform recorded levels to discharge, are a prime error source in flood studies, the ratings for the site were plotted to detect gross errors. In one case (45504, Makarau at Coles) where there was considerable divergence between a series of high stage rating curves, a revision was prepared.

Plots of flow hydrographs were used to examine the continuity of data and identify years where the maximum had not been recorded.

Using the extracted peak flow data up to 2006, the annual maxima flood series were fitted with extreme value type 1 (EV1 or Gumbel) frequency distributions. Where the fit of the annual maxima data was unsatisfactory, the same distribution was fitted to biennial (and in one case each triennial and quadrennial) maxima, which is the approach used by McKerchar and Pearson (1989). Figure 17 is an example, for station 3506 (Maungaparerua at Tyrees Ford) of the Gumbel distribution fit using annual and biennial sampling. The 1/100 AEP estimate reduces from 104 m^3/s to 99 m^3/s, but the 95% confidence limits increase from ±19 m^3/s to ±21 m^3/s.

Table 2: Northland streamflow recorders.

Site No	River	Location	Record since	Area (km^2)	Authority
1316	Awanui	School Cut	24-Jan-58	222	NIWA
1903	Oruru	Saleyards	15-Dec-88	79	NIWA
3506	Maungaparerua	Tyrees Ford	22-Nov-67	11.1	NIWA
3722	Waitangi	Wakelins	22-Feb-79	302	NIWA
3819	Waiharakeke	Willowbank	18-Apr-67	229	NRC
4901	Ngunguru	Dugmores Rock	22-Aug-69	12.5	NRC
5527	Waiarohia	Lovers Lane	17-Oct-79	18.6	NRC
5528	Raumanga	Bernard St	31-Oct-79	16.3	NRC
5901	Ruakaka	Flyger Rd	19-Mar-84	45.3	NRC
6015	North	Applecross Rd	26-Nov-82	38.4	NRC
6016	Waihoihoi	St Marys Rd	27-Jan-84	25.1	NRC
6018	Ahuroa	Braigh Flats	29-Aug-83	57	NRC
45504	Makarau	Coles	31-Mar-89	53.7	NIWA
45702	Waiwhiu	Dome Shadow	23-Nov-67	8.03	NIWA
46611	Kaihu	Gorge	2-Mar-70	116	NRC
46618	Mangakahia	Gorge	8-Dec-60	246	NIWA
46626	Mangakahia	Titoki Br	28-Feb-83	798	NRC
46627	Waiotu	SHB	20-Oct-87	125	NRC
46632	Whakapara	SHB	8-Dec-59	162	NRC
46644	Wairua	Purua	21-Mar-60	544	NRC
46646	Mangere	Knights Rd	8-Feb-83	79	NRC
46647	Wairua	Wairau Br	6-Sep-61	707	NRC
46651	Manganui	Permanent Stn	20-May-60	411	NRC
46674	Mangahahuru	County Weir	15-Dec-68	20.5	NRC
47804	Waipapa	Forest Ranger	31-Mar-78	122	NIWA

A problem with this record is that the recorder was destroyed by a flood in 1981. A maximum level of 4.23 m above the weir sill was supplied by Mr G. Mackay of NIWA's Whangarei field team, but this level was not archived with data for the recorder, suggesting that it may not be a sound value. Considerable extrapolation of the archived rating curve indicates a peak discharge of 290 m^3/s, which is nearly three times the second largest peak flow of 104 m^3/s recorded in March 2007. However, a two-day rainfall recorded by raingauge 532810 (Maungaparerua at Tyrees) for 19-20 March 1981 was 302 mm, which is significantly less than the total for the 28-29

March 2007 storm total of 402 mm (Figure 3). It was concluded that the peak value for 1981 is not known reliably and frequency analysis presented does not use it.

For the Awanui at School Cut, flows for the 2007 floods are estimated as described in Henderson and Wild (2005). This involves using the flow record for the Tarawhaturoa Stream to estimate spillage from the Awanui River across State Highway One upstream of the recorder. The frequency analysis results used here are as given in the Henderson and Wild (2005) report for the 1958-2004 data. The results apply for the Awanui River upstream of the location where spillage out of the river channel across the highway occurs.

All the flood frequency results are presented in Table 3. This table includes estimates of the peak flows for the two events, estimates of the 1/50 and 1/100 AEP floods, associated ±95 % confidence limits and the 2007 floods as fractions of the 1/50 and 1/100 AEP estimates. To gain an impression of the extent of severe flooding in Northland, maps were prepared with catchment areas shaded according to the flood ranks (Figures 18 and 19) and the fraction of the 1/50 AEP estimate (Figures 20 and 21).

5. Results

5.1. Storm rainfall

The common features of the storms are depressions moving south from the north Tasman Sea down the west coast of the North Island and being squeezed against blocking high pressure systems to the east, with the result that moist subtropical air masses are drawn over Northland leading to very high rainfalls.

For the March storm the automatic raingauge data (Figures 3 and 4) shows rain fell fairly steadily throughout the storm, with the bulk of the rain occurring between 0900 h on 28 and 30 March. This justifies including the manual gauge data over the two days to characterise the extent of the storm. For the July storm, the main burst of rain commenced at about midnight on 9 July (Figures 9 and 10) and continued through to the morning of 11 July: the manual gauge data from 0900 h on 9 July to 0900 h on 11 July encompass this storm.

Figures 11 and 12 illustrate the spatial distribution of the storm rainfalls. In the March storm (Figure 11) an extensive area of the eastern side of the Northland peninsula from Taupo Bay in the north to Mangawhai Harbour in the south received in excess of 200 mm of rain in two days and significant areas between Whangarei and Whangaroa received more than 350 mm. The July storm rainfall distribution was somewhat

similar with higher falls in the east, but in this case falls exceeding 100 mm covered most of the Northland peninsula, excluding the far north. Heaviest falls, exceeding 250 mm, occurred around Whangaroa Harbour and Kaeo.

Figures 13 and 14 present the storm rainfall intensities for 6, 12, 24 and 48 hours as measured at a number of automatic raingauges for the two storms and compares them with the intensity estimates as given by the High Intensity Rainfall Design System (HIRDS) (Thompson, 2002). These plots show that for the March storm, 1/100 AEP rainfalls were exceeded at a number gauge locations including Kaeo, Kerikeri, Mangaparerua, Oakura Bay, Puhipuhi, Polerain, Whangarei Aero AWS, NRC Water St and Marsden Point. For the July storm, 1/100 AEP exceedences occurred at Kaeo only.

The maps in Figures 15 and 16 show the areas where the 48 hour rainfalls for both the automatic and manual raingauges exceeded 1/10, 1/50 and 1/100 AEP values, as given by HIRDS. The March storm intensity was particularly severe and the coverage extensive: as seen in Figure 15, much of the eastern side of the Northland peninsula experienced rainfalls with AEPs greater than 1/100.

In the July storm (Figure 16), severe rainfalls (greater than 1/100 AEPs) occurred only around Whangaroa Harbour and Kaeo. Patches of rain with intensity in the range 1/10 AEP to 1/50 AEP occurred elsewhere, with a band across the peninsula from Whangarei to Dargaville.

5.2. Floods

The flood frequency results are presented in Table 3. This table provides a comparison of the flood magnitudes with estimates of 1/50 and 1/100 AEP flood quantiles using the data recorded up to 2006, except that the Awanui data are to 2004. To complement the rainfall intensity maps, figures were prepared with catchment areas shaded according to the flood ranks (Figures 18 and 19) and the fraction of the 1/50 AEP estimate (Figures 20 and 21). Confidence limits are included with the quantile estimates: these depend of the length of record, the year-to-year variation in floods, the AEP and the sampling method used for flood frequency (annual, biennial etc.). They range from ±14 to ±40% and typical (median) estimates are ±20% to ±21% .

These maps support the rainfall intensity maps. The catchments experiencing the extreme floods are consistent with the areas receiving the most severe rainfalls. In the March storm, the record high floods occurred in the catchments on the eastern side of the Northland peninsula: eight streamgauges recorded record high flows and another

Table 3: Summary of flood frequency analyses.

Site No	River	Peak flow March	Rank	Peak flow July	Rank	$Q_{1/50}$	±95% CL	$Q_{1/100}$	±95% CL	Ratio to $Q_{1/50}$ March	Ratio to $Q_{1/50}$ July	Ratio to $Q_{1/100}$ March	Ratio to $Q_{1/100}$ July	Sampling interval for maxima
1316	Awanui	69	>10	287	2	331	53	368	62	0.21	0.87	0.19	0.78	annual
1903	Oruru	76	8	100	2	110	21	119	24.4	0.69	0.91	0.64	0.84	annual
3506	Maungaparerua	104	1	53.2	>10	89.1	17	98.7	21	1.17	0.60	1.05	0.54	biennial
3722	Waitangi	677	1	389	5	571	162	644	196	1.19	0.68	1.05	0.60	biennial
3819	Waiharakeke	109	8	158	3	186	33	207	38.8	0.59	0.85	0.53	0.76	annual
4901	Ngunguru	91	7	30.8	>10	131	20	146	29.1	0.69	0.24	0.62	0.21	annual
5527	Waiarohia	70.7	2	54.8	4	94.3	36	108.6	43.1	0.75	0.58	0.65	0.50	biennial
5528	Raumanga	63.4	2	41.9	5	58	14	65.1	16	1.09	0.72	0.97	0.64	annual
5901	Ruakaka	116	1	no data	-	100	23	111	26.7	1.16	-	1.05	-	annual
6015	North	72.5	1	no data	-	81.2	25	90.4	29.6	0.89	-	0.80	-	biennial
6016	Waihoihoi	29.4	3	no data	-	35.3	7	38.6	8.3	0.83	-	0.76	-	annual
6018	Ahuroa	120	3	no data		159	36	176	42.7	0.75	-	0.68	-	annual
45504	Makarau	57.3	>10	165	>10	444	161	502	195	0.13	0.37	0.11	0.33	biennial
45702	Waiwhiu	26.5	>10	24.1	>10	73.3	14	82.2	16.4	0.36	0.33	0.32	0.29	annual
46611	Kaihu	56.4	>10	295	2	349	66	390	77.6	0.16	0.85	0.14	0.76	annual
46618	Mangakahia	410	>10	611	>10	1164	196	1302	231	0.35	0.52	0.31	0.47	annual
46626	Mangakahia	541	>10	1324	1	1227	284	1366	333	0.44	1.08	0.40	0.97	annual
46627	Waiotu	247	1	200	2	203	44	222	51.2	1.22	0.99	1.11	0.90	annual
46632	Whakapara	818	1	519	6	677	135	767	159	1.21	0.77	1.07	0.68	annual
46641	Waipao	15.2	>10	no data	-	25.8	5	28.4	6.2	0.59	-	0.54	-	annual
46644	Wairua	262	>10	no data	-	342	66	376	83.1	0.77	-	0.70	-	quadrennial
46646	Mangere	97.4	1	no data	-	103	18	111	22	0.95	-	0.88	-	biennial
46647	Wairua	359	6	402	3	478	70	527	82.7	0.75	0.84	0.68	0.76	annual
46651	Manganui	181	>10	297	2	324	59	359	70.7	0.56	0.92	0.50	0.83	biennial
46674	Mangahahuru	18.9	1	no data	-	21	3	22.6	3.6	0.90	-	0.84	-	biennial
47804	Waipapa	475	2	626	1	570	118	635	139	0.83	1.10	0.75	0.99	annual

three recorded their second highest flows. The July floods were more extensive over the Northland region, but generally less severe: two streamgauges recorded their highest flows and five recorded their second highest. The frequency estimates (Figures 20 and 21) indicate that 1/50 AEP estimates were exceeded at six streamgauges in March and at two in July.

5.3. Antecedent rainfall and soil moisture

Culmulative rainfalls from 1 July 2006 and 2007 and monthly totals and means are presented in Figure 22 for Kerikeri EWS and Whangarei Aero AWS. These plots show that although rainfalls for September to December 2006 were below normal, January and February rainfalls for 2007, prior to the March storm, were near or above normal. Similarly, rainfalls for May and June 2007, prior to the July storm, were somewhat below normal.

Measured soil moisture levels, as percentages of soil volume, are plotted in Figure 23 for Kaitaia, Kerkeri EWS and Dargaville EWS. The main feature of these plots is the seasonal pattern of dry conditions in summer and wet conditions in winter. They show that prior to the March storm, soil moisture levels were low, but not unusually so for the time of year, and that prior to the July storm, conditions were at the normal winter levels which are close to field capacity. It follows that storm loss rates would have been greater in March than in July, and had the antecedent conditions in March been wetter, the runoff and resulting floods would have been higher.

5.4. Long term variability

There is evidence that decadal-scale variations of the frequency and intensity of occurrences of the El Niño Southern Oscillation phenomenon (ENSO) are associated with periods of more frequent storms and floods, particularly in the north and northeast of the North Island and the south and west of the South Island (Salinger et al., 2001; McKerchar and Henderson, 2003). For example in the Bay of Plenty region, the period from 1947-1977 is recognised as being “flood rich”, whereas the period 1978-1999 is considered “flood poor”, and it has been suggested that the post-1999 period, in which several major floods have occurred, may be more akin to the 1947-1977 period. With respect to floods in Northland, it is not clear whether similar patterns apply, mainly because Northland has few systematic flood records from the 1940s and 1950s. However, a focussed study using the longer Northland rainfall records may reveal useful information.

6. Conclusions

The floods that Northland experienced in March and July 2007 had quite similar characteristics, notably an active trough moving southeast from the north Tasman Sea against a blocking zone of high pressure to the east of the country.

The March storm yielded very high rainfalls over eastern parts of the Northland peninsula. Some locations received over 400 mm in two-days and 48 h falls exceeded 1/100 AEP estimates over much of the eastern side of the Northland peninsula.

The July storm was more widespread over the region. Only a few gauges had two-day totals exceeding 300 mm, and only an area around Whangaroa Harbour and Kaeo had 48 hour totals above 1/50 AEP levels.

The March and July 48 hour storm totals for the Kaeo automatic raingauge were 323 mm and 289 mm respectively. Rainfall rates during these storms both exceed the Kaeo 1/100 AEP estimates.

Flood severity generally followed the rainfall patterns. In March record high floods occurred in a number of rivers on the eastern side of Northland. Flooding was more widespread in July, but only two rivers of those analysed had record high flows and these exceeded the 1/50 AEP estimates.

Soil moisture data show that the region was dry, but not unusually so, prior to the March storm. Higher runoff rates and more severe flooding would have occurred had the region had saturated soils beforehand. Soil moisture levels were close to winter field capacity levels prior to the July storm and runoff rates were higher.

Decadal-scale variations in El Niño Southern Oscillation patterns suggest that in Northland the period 1978-1999 may have been relatively quiescent and that the post-1999 years may be experiencing severe weather and floods that are more similar to patterns experienced in 1947-1977. This topic may be worth exploring further.

7. Acknowledgements

This report makes use of data collected over many years by NIWA and NRC staff and collated by Kathy Walter. The synoptic charts reproduced in Figures 1 and 2 are provided courtesy of Meteorological Service of New Zealand Ltd. C.S. Thompson, R.A. Woods and J. Sturman are thanked for assistance preparing the figures.

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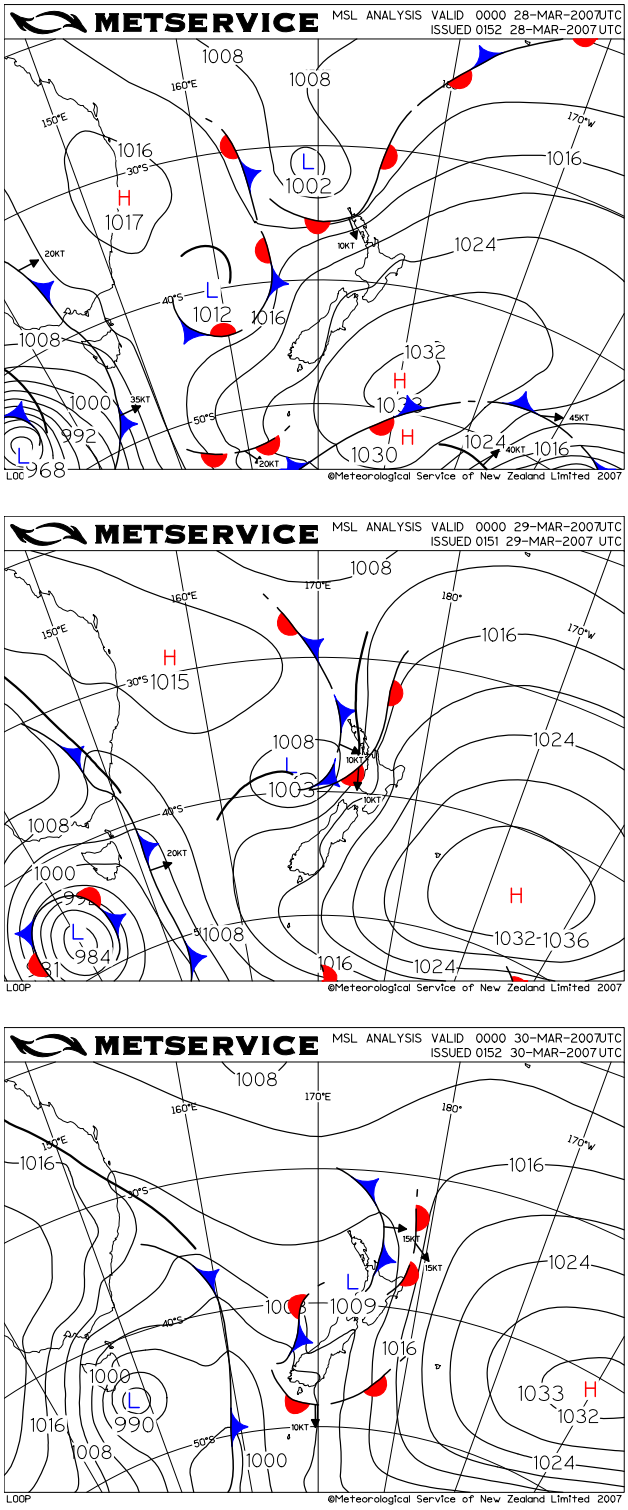

Figure 1: Surface analysis chart for 28 to 30 March 2007. (Maps courtesy of Meteorological Service of New Zealand Ltd.)

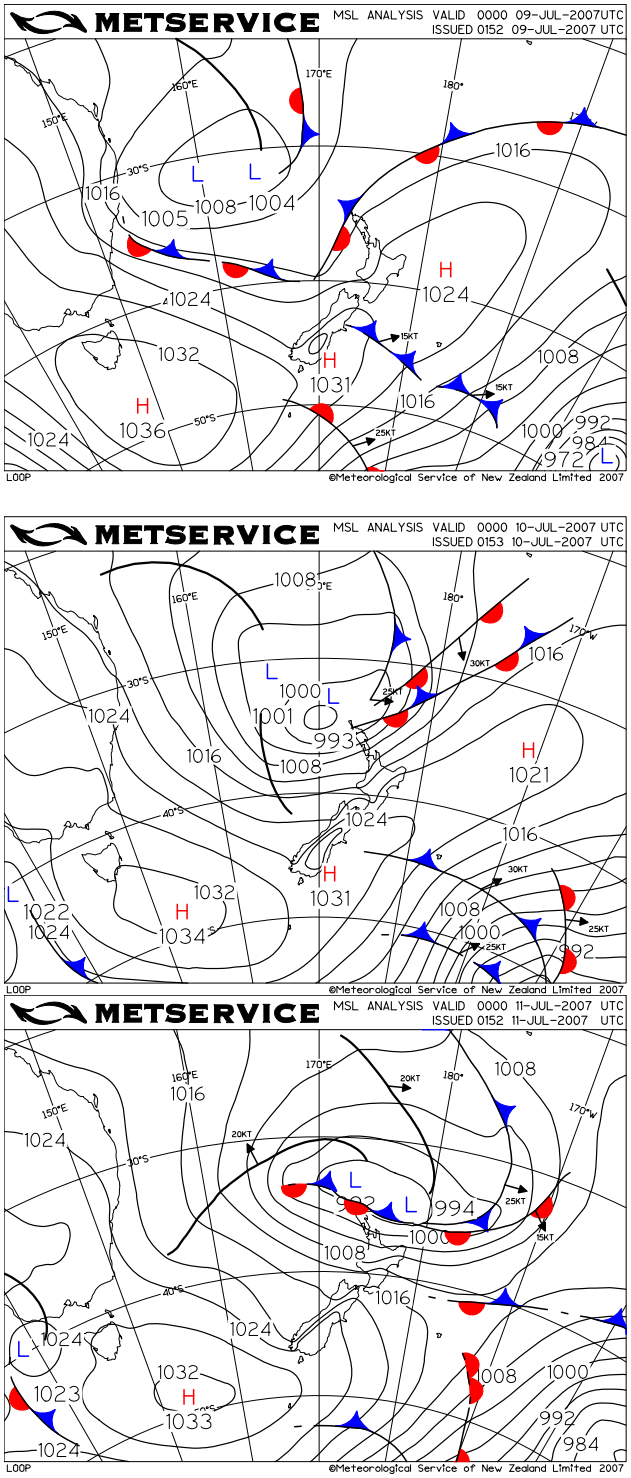

Figure 2: Surface analysis chart for 9 to 11 July 2007. (Maps courtesy of Meteorological Service of New Zealand Ltd.)

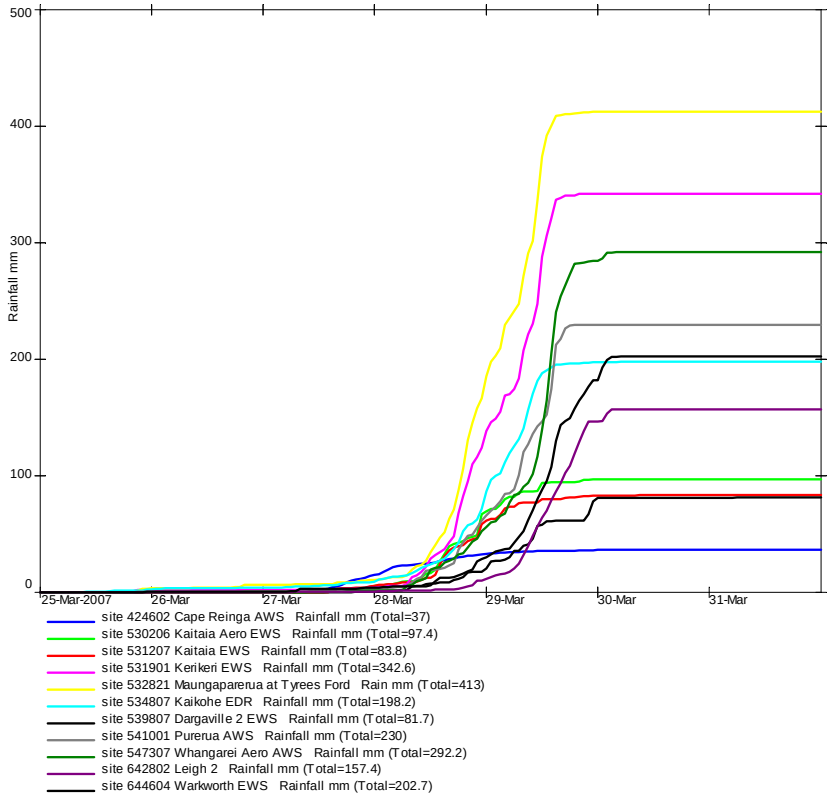

Figure 3: Cumulative March storm rainfalls for the NIWA & MetService-operated automatic raingauges.

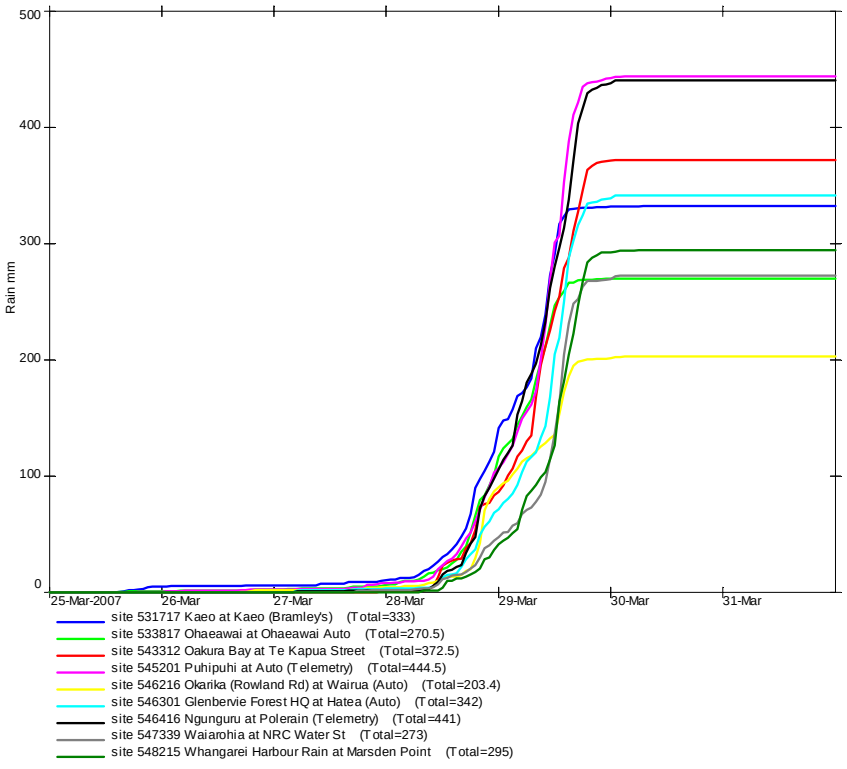

Figure 4: Cumulative March storm rainfalls for some of the NRC-operated automatic raingauges.

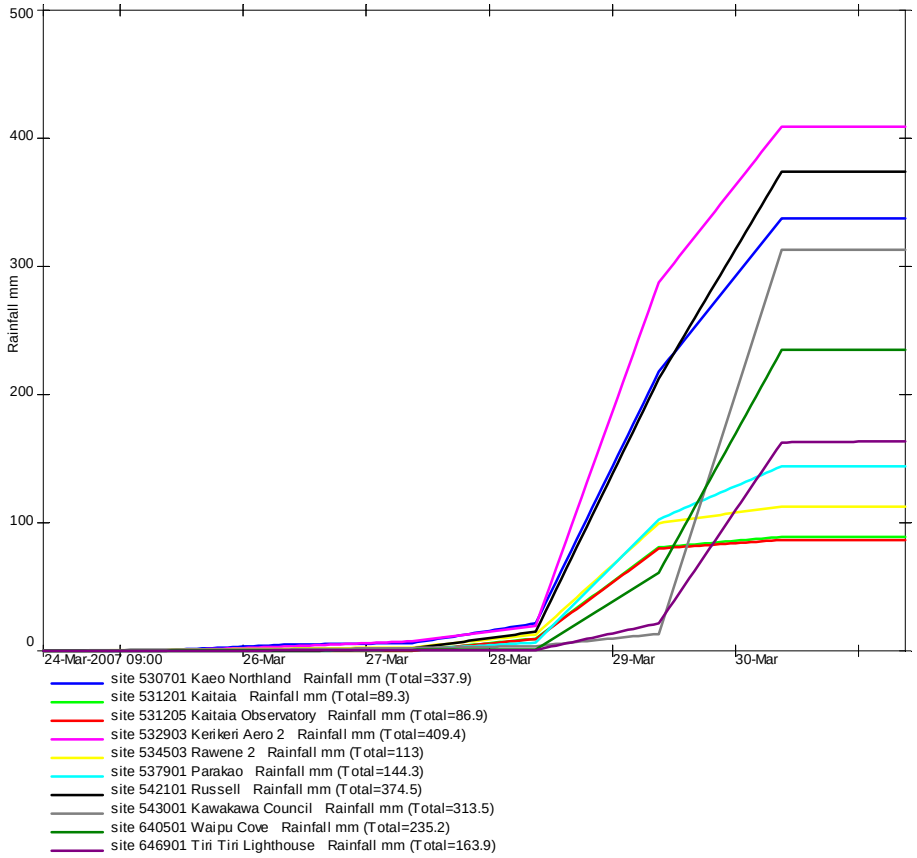

Figure 5: Cumulative March storm rainfalls for the NIWA-operated daily raingauges.

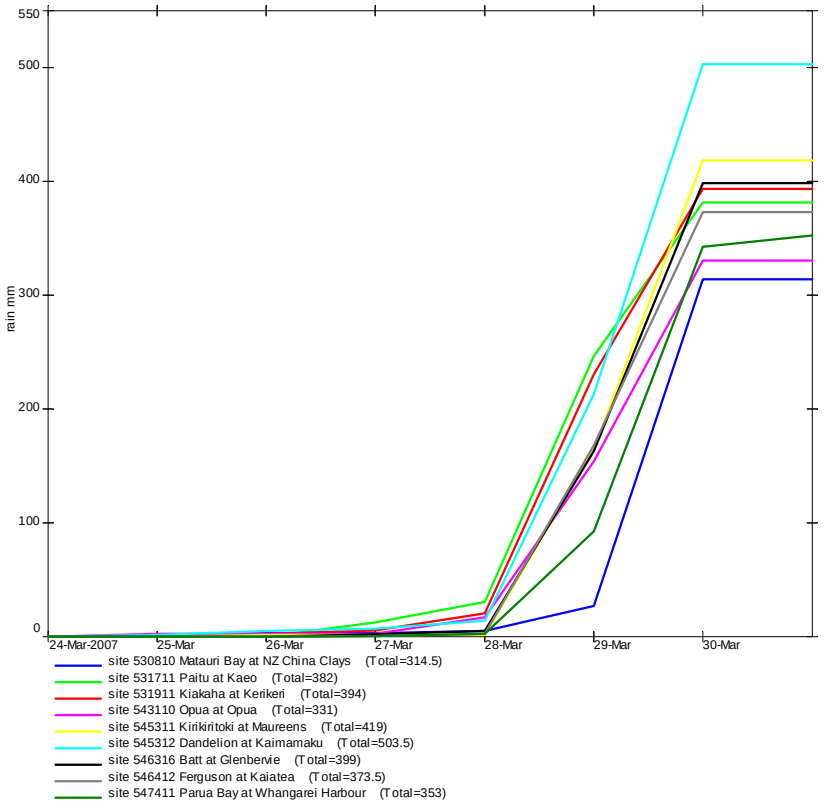

Figure 6: Cumulative totals for 10 NRC daily-read raingauges for the March storm.

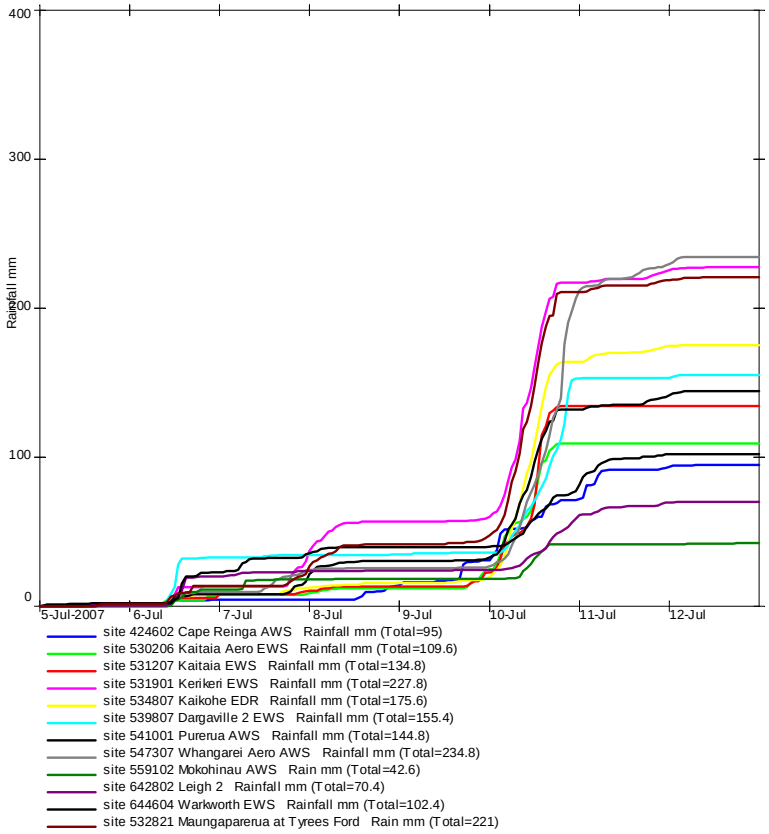

Figure 7: Cumulative July storm rainfalls for the NIWA & MetService-operated automatic raingauges.

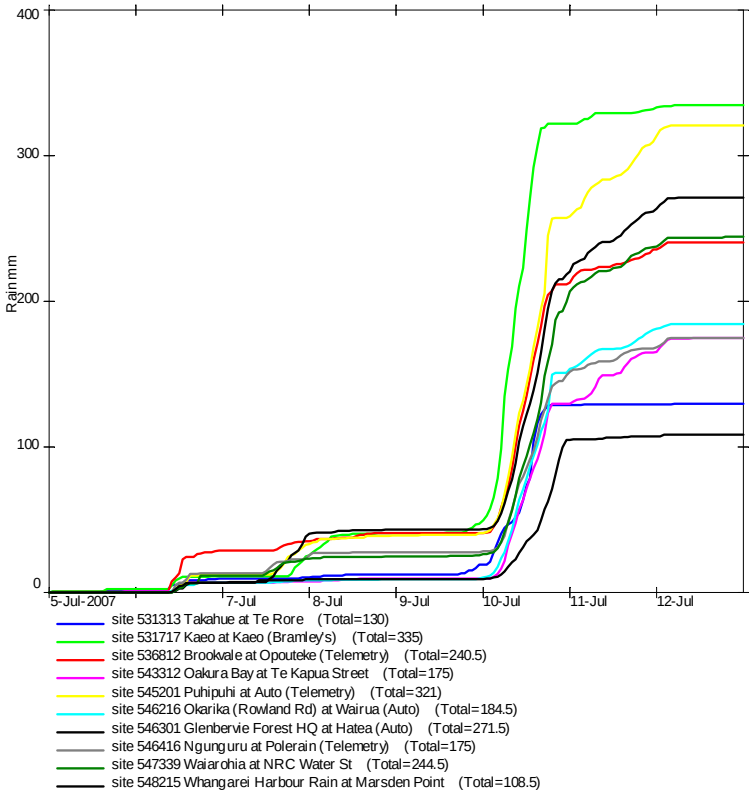

Figure 8: Cumulative July storm rainfalls for 10 NRC-operated automatic raingauges.

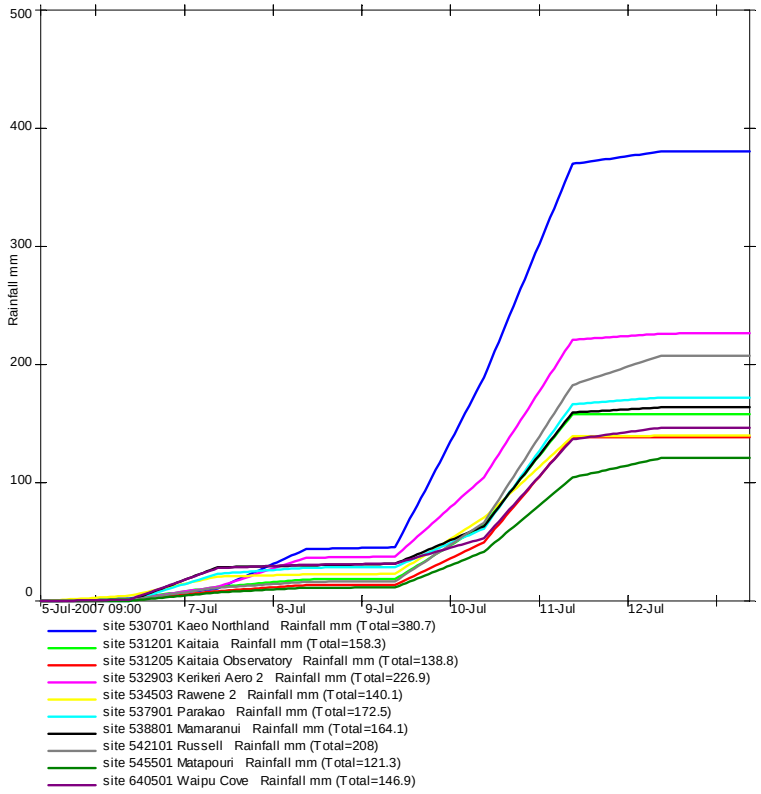

Figure 9: Cumulative July storm rainfalls for 10 NIWA-operated daily raingauges.

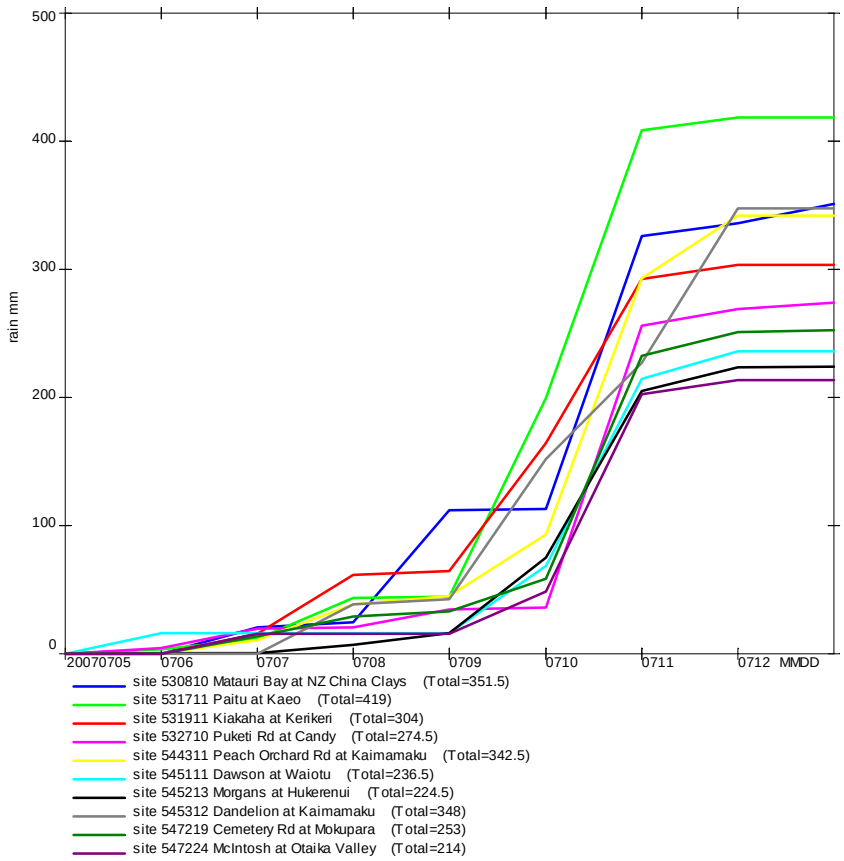

Figure 10: Cumulative July storm rainfalls for 10 NRC-operated daily raingauges.

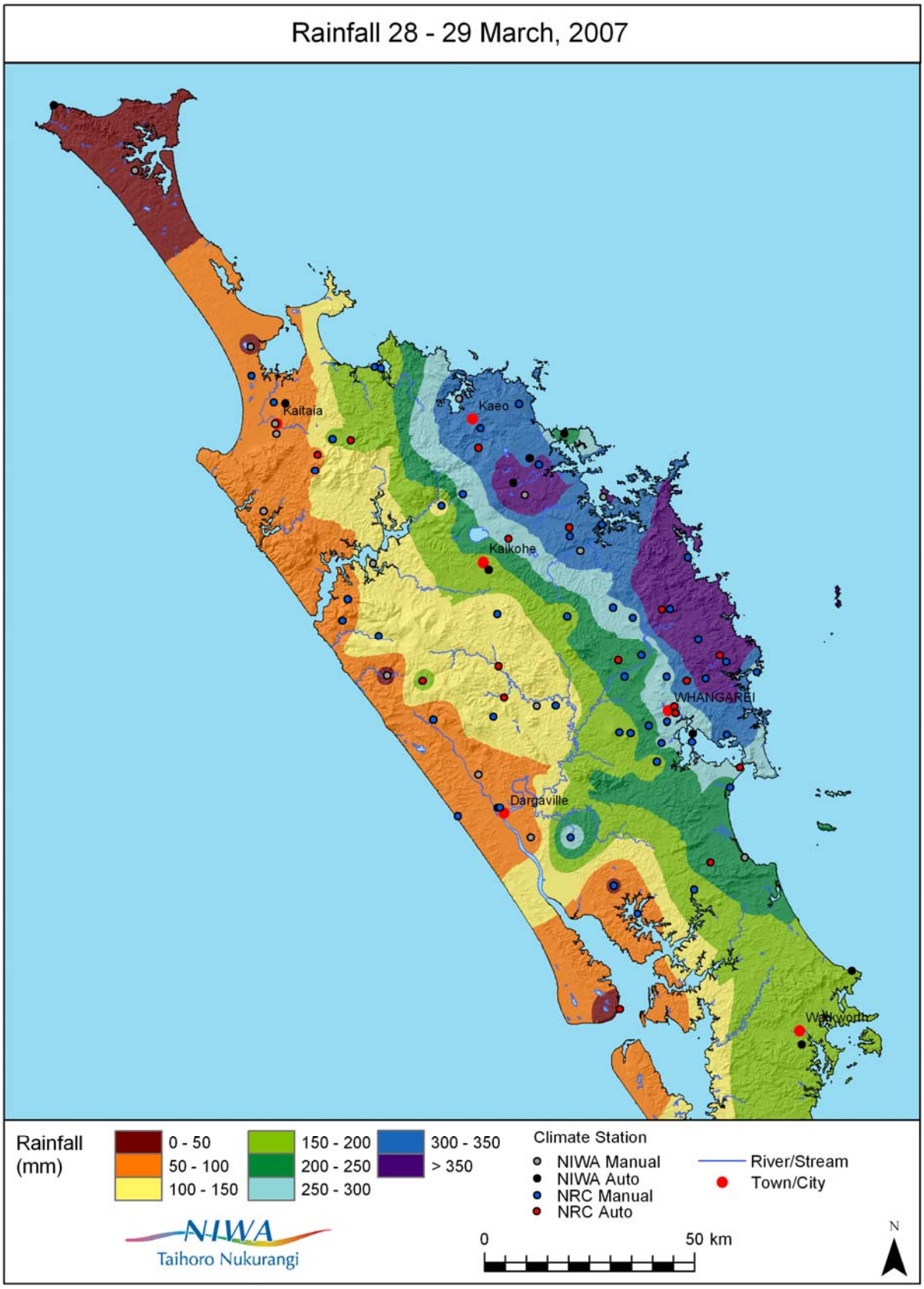

Figure 11: Map showing Northland rainfall depths for the two-day period ending at 0900 h on 30 March 2007.

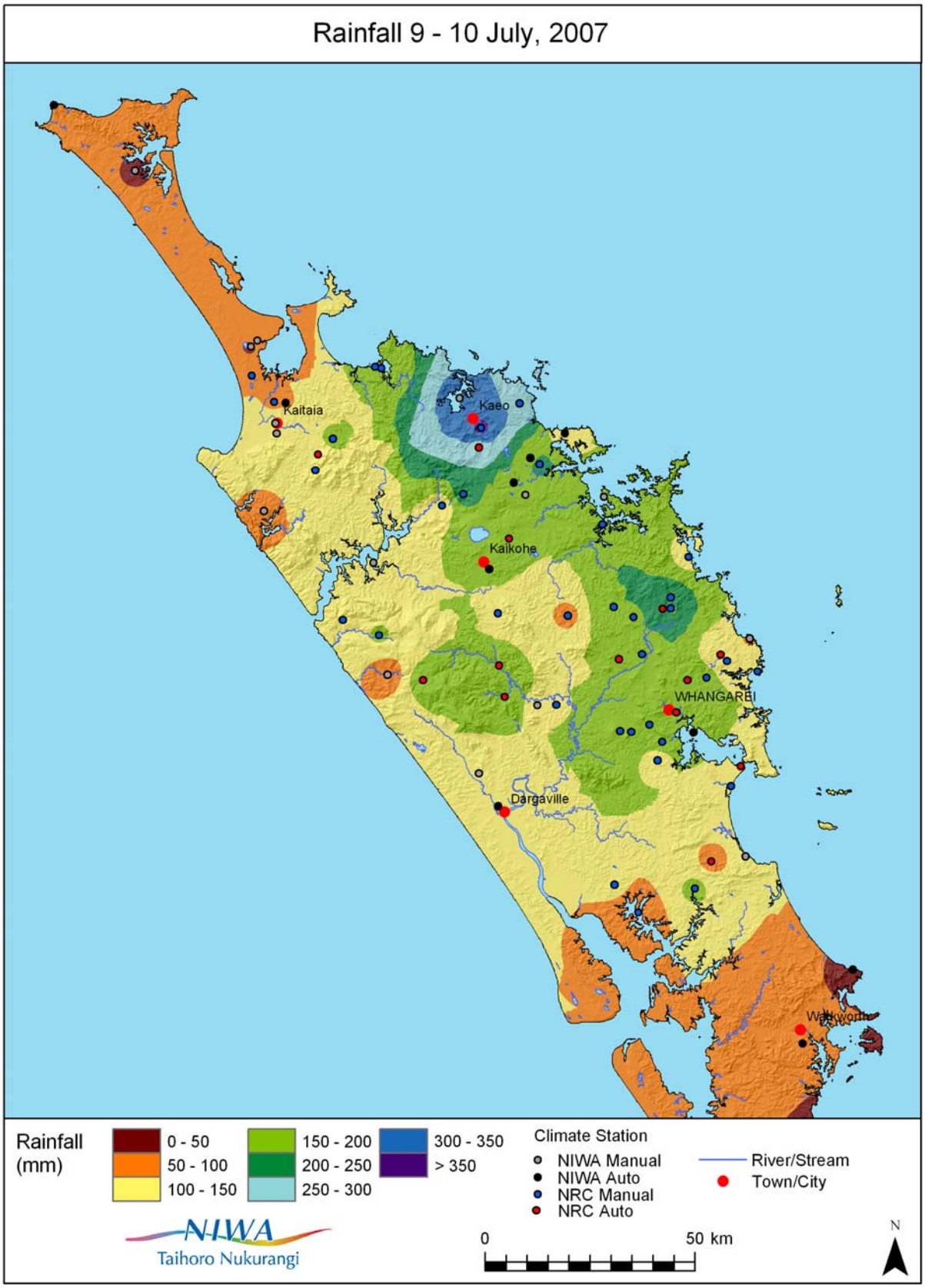

Figure 12: Map showing Northland rainfall depths for the two-day period ending at 0900 h on 11 July 2007.

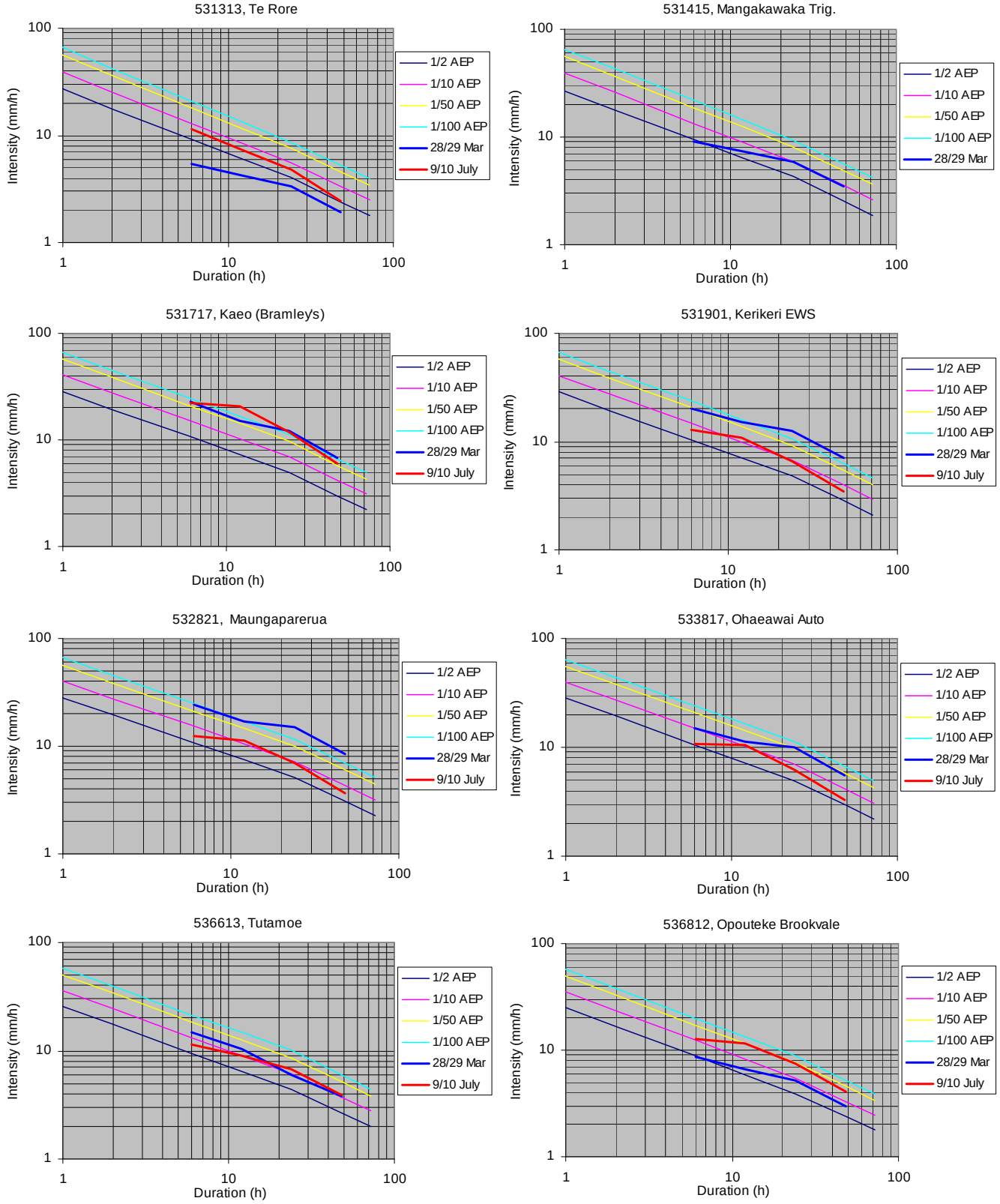

Figure 13: March and July storm intensities for 6, 12, 24 and 48 h compared with HIRDS analyses data for the gauge locations.

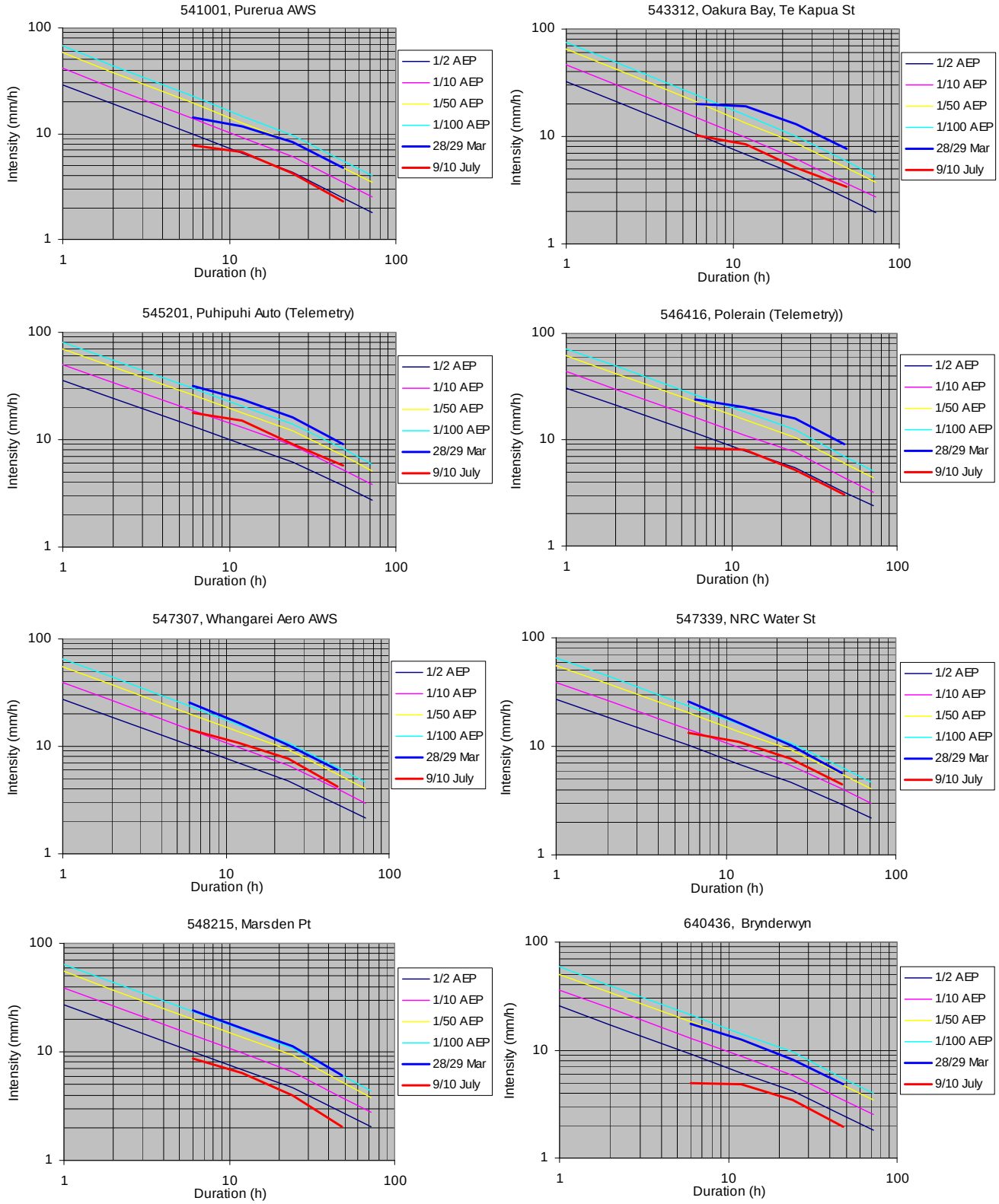

Figure 14: March and July storm intensities for 6, 12, 24 and 48 h compared with HIRDS analyses data for the gauge locations.

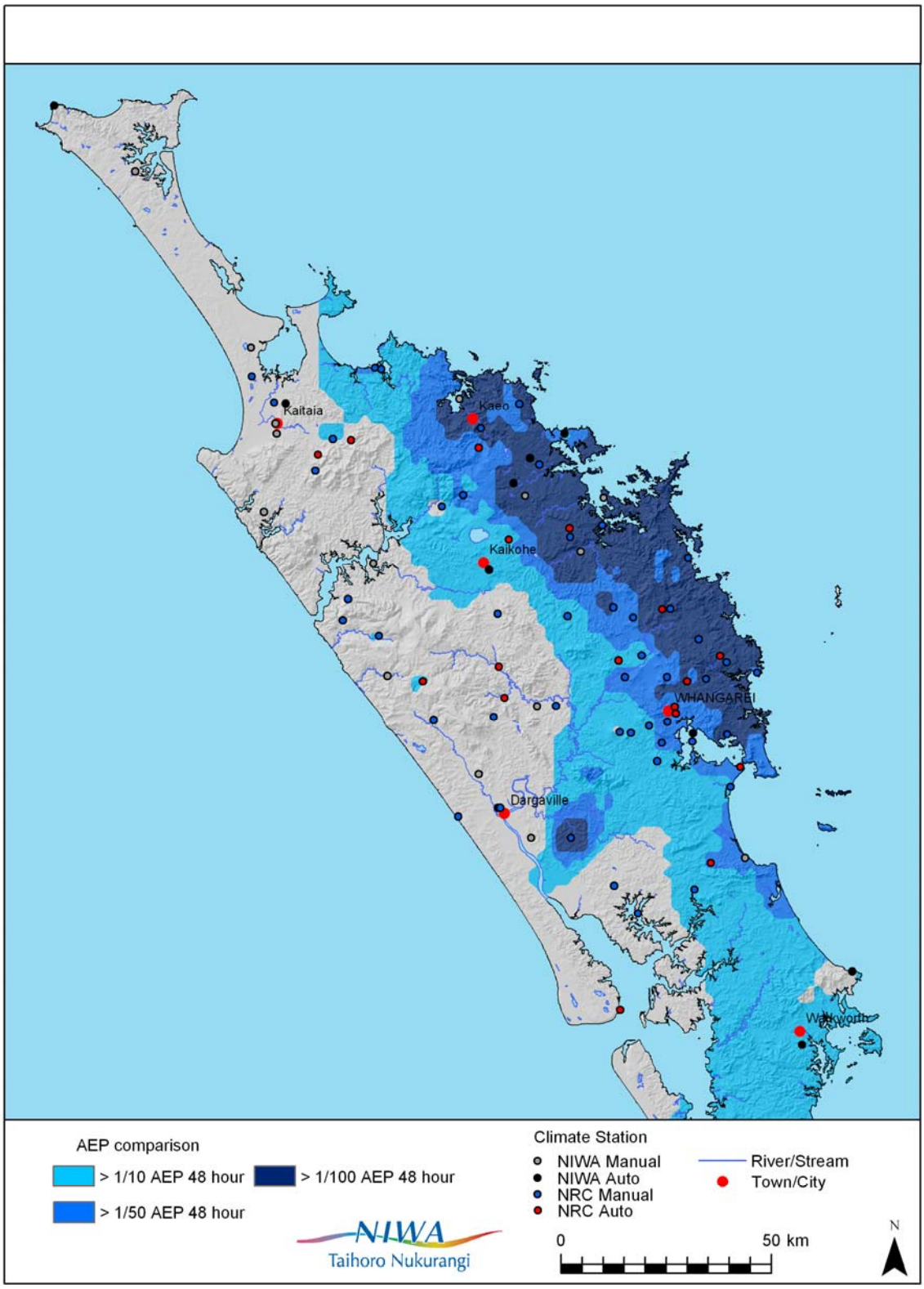

Figure 15: Areas receiving greater than 1/10, 1/50 & 1/100 AEP rainfalls on 28-29 March 2007.

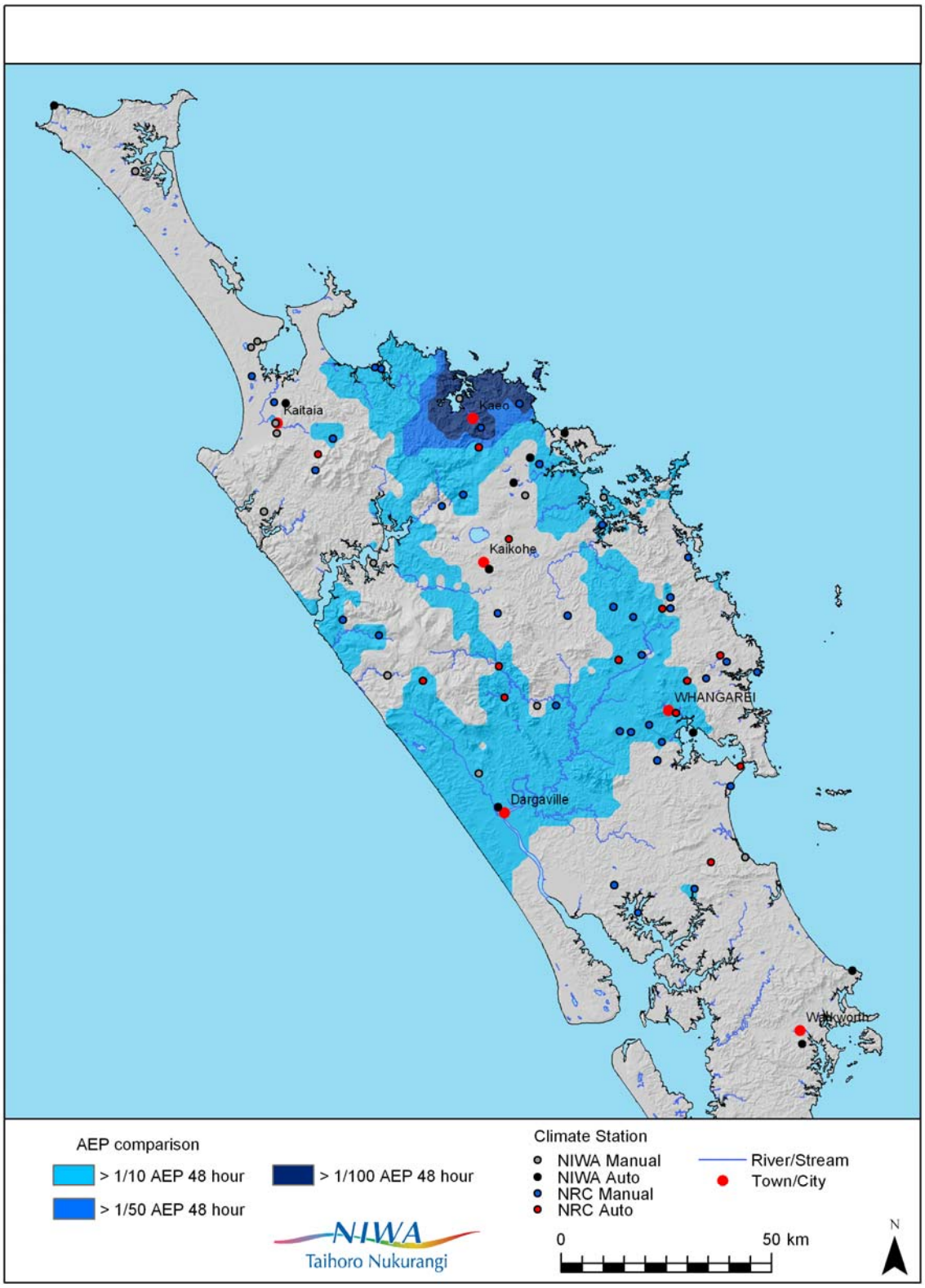

Figure 16: Areas receiving greater than 1/10 1/50 & 1/100 AEP rainfalls on 9-10 July 2007.

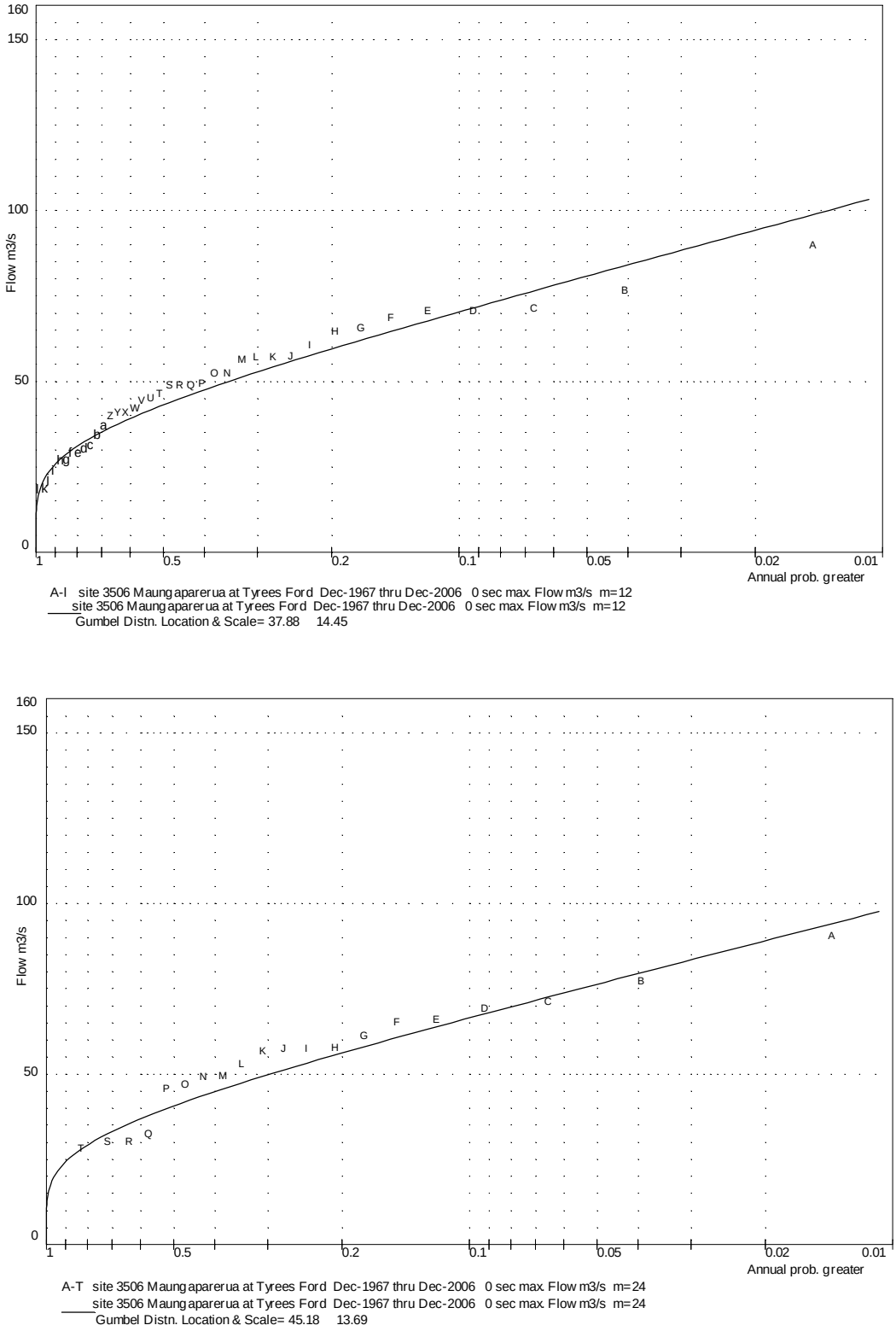

Figure 17: Comparison of annual (upper panel) and biennial (lower panel) data sampling in fitting the Gumbel distribution to annual maxima for station 3506, Mangaparerua at Tyrees Ford. The 1/100 AEP estimate is reduced from 104 m^3/s to 99 m^3/s.

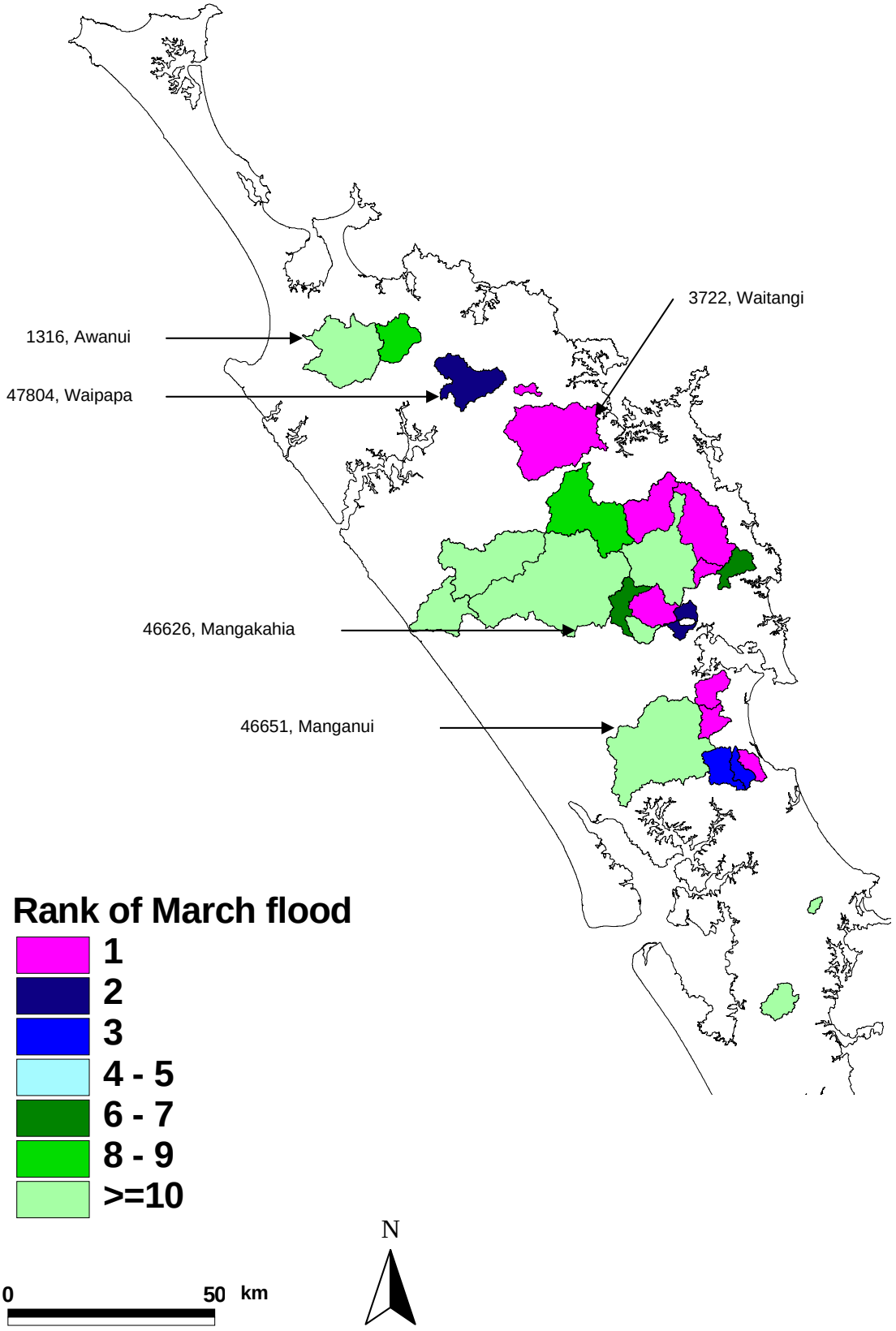

Figure 18: Ranks of the March flood peaks.

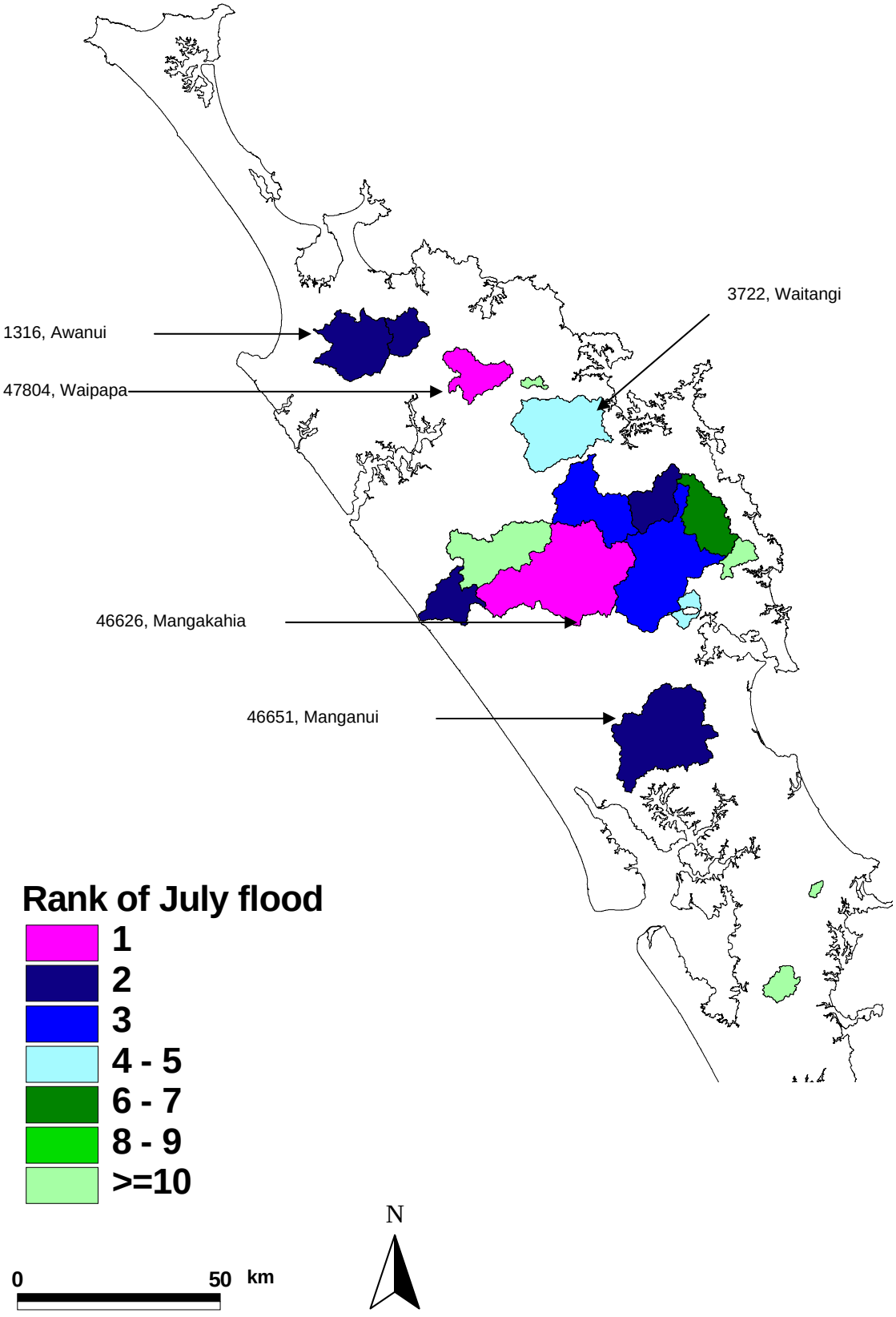

Figure 19: Ranks of the July flood peaks.

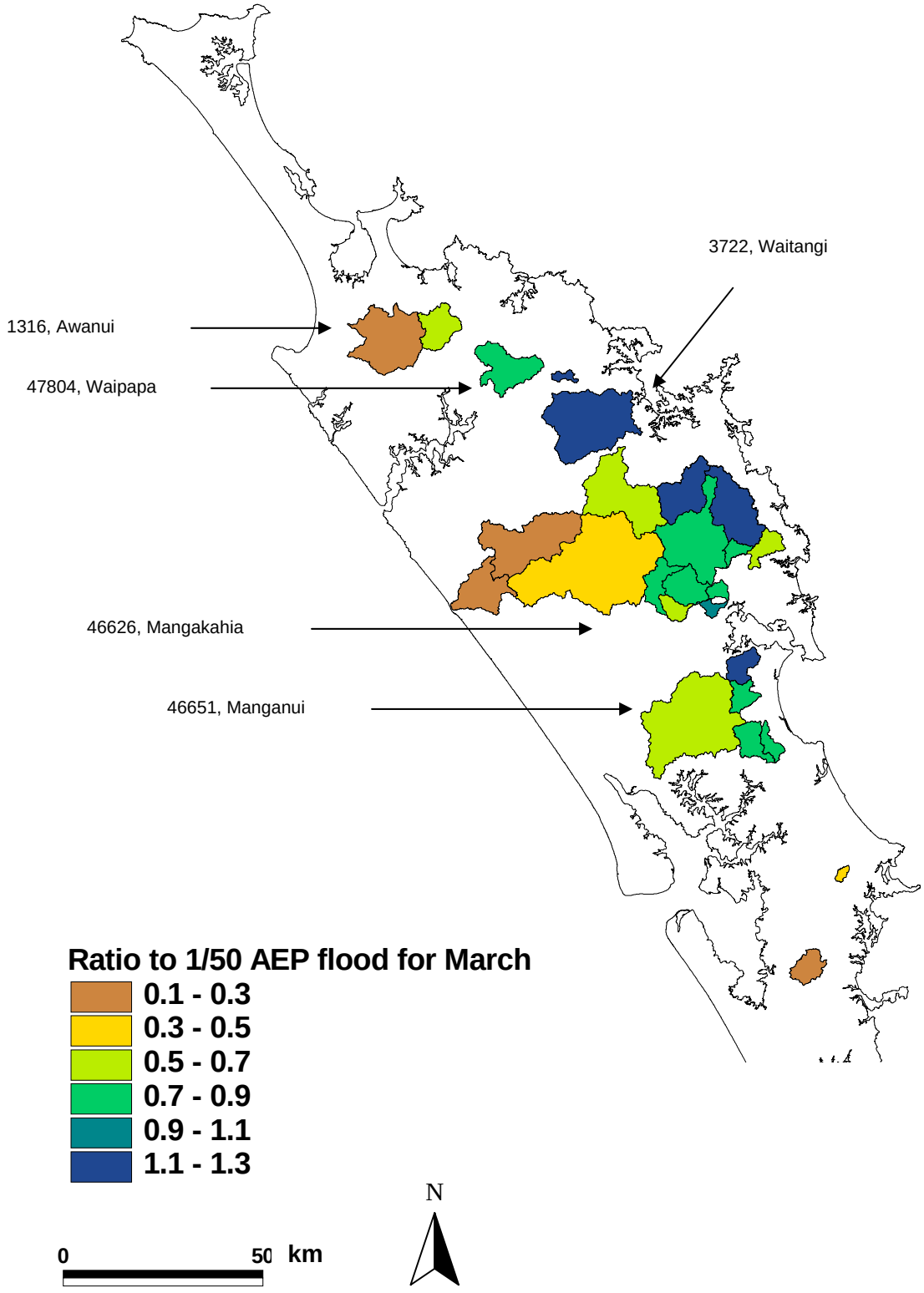

Figure 20: Fraction of the March flood peak compared with the 1/50 AEP estimate for the river.

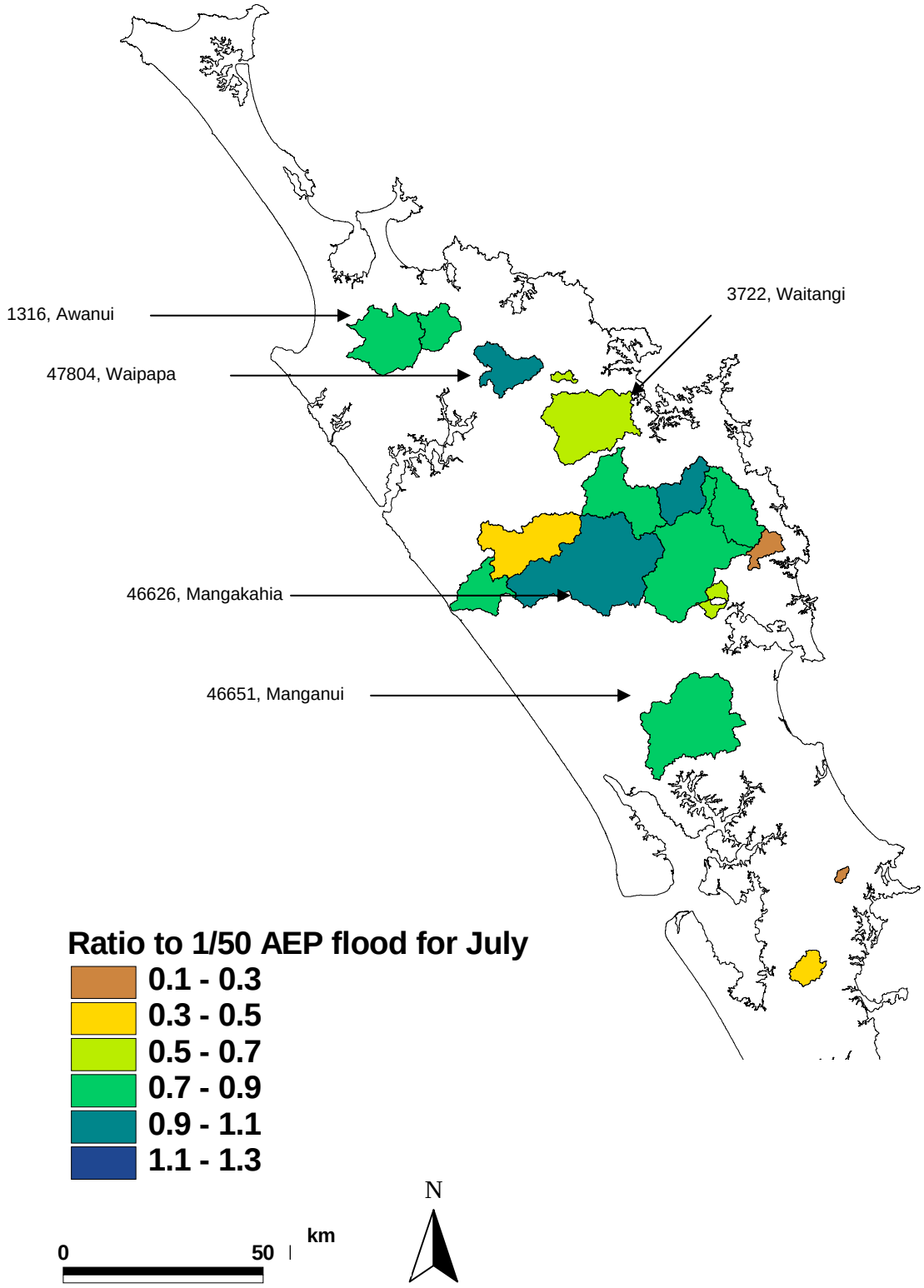

Figure 21: Fraction of the July flood peak compared with the 1/50 AEP estimate for the river.

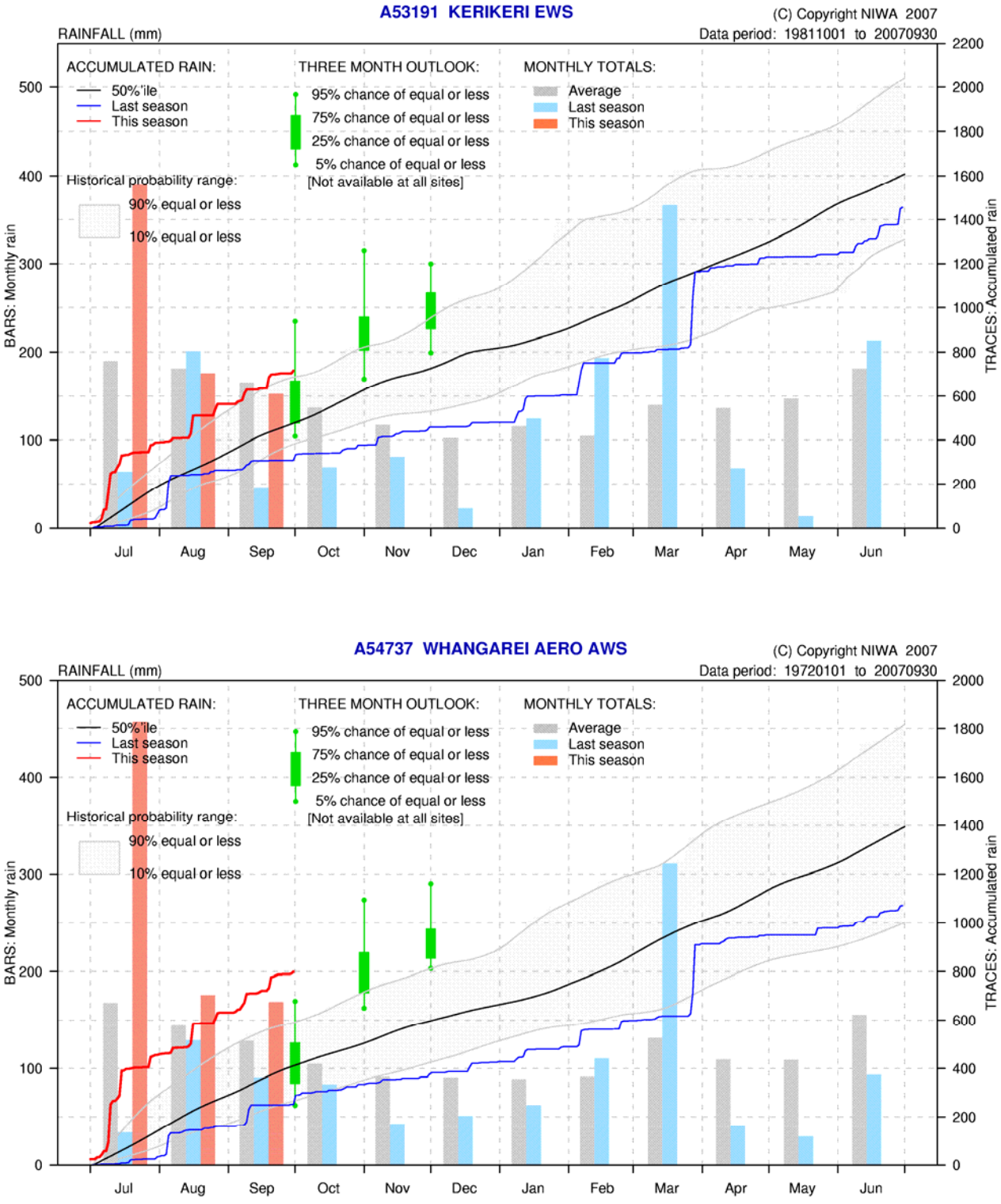

Figure 22: Culmulative, seasonal and monthly rainfalls for Kerikeri EWS and Whangarei AWS.

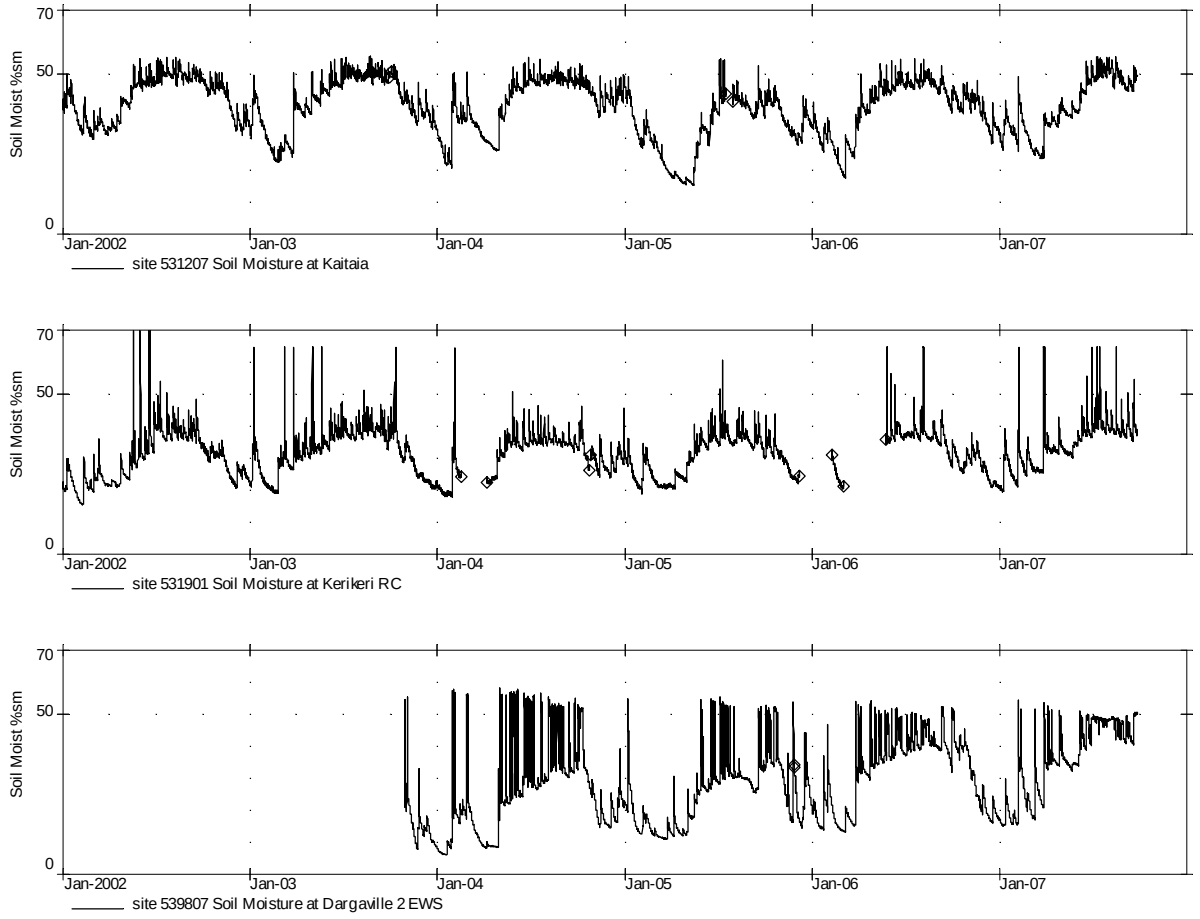

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Figure 23: Soil moisture levels recorded at Kaitaia, Kerikeri & Dargaville.